Advanced Teaching Methods for the Technology Classroom

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Advanced Teaching Methods for the Technology Classroom

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Preface

Technology teachers need texts that are forward-looking in content and methods, but also cover the ground of proven, reliable techniques of curriculum and instruction (C&I). This book provides just such an encounter between "what to do," "how to do it," and "why to do it." Theory and practice in technology studies have changed in unprecedented ways during the last twenty years. In design, engineering, technology, and information and communication technology (ICT), the conceptual changes in C&I are remarkable. At least conceptually, all the ingredients for a transformation from industrial (arts) education to technology education were in place. The same ingredients were put into place to transform audiovisual education and computer science in the schools to ICT or new media education. During the 1980s and 1990s, research into the cultural aspects of technology also went through a transformation of theory and method. At the same time, education (academic, vocational, etc.) and teacher education witnessed an immense reconceptualization, although this was not entirely born out in practice. Simply put, there were tremendous changes within technology studies over the past two decades.

Advanced Teaching Methods for the Technology Classroom is a guide for education *about*, *through,* and *for* technology. It is intended to help you teach and, by consequence, your students learn, *about*, *through,* and *for* technology. To simplify this intention, when we teach *about* technology, we are dealing with content and dispositions; when we teach *through* technology, we are dealing with processes and skills; teaching *for* technology refers to occupations and roles. By themselves, none of these three orientations provides an adequate education. A conscious integration of the three orientations is what differentiates the approach in this book from more narrow studies *about* technology or training *for* technology. Effective technology teaching requires that we balance these three orientations.

The operative theme of this book is technological pluralism: 1) an integration of pedagogical and philosophical *orientations* to learning about, through, and for a wide *range of technologies;* and 2) a synthesis of *disciplines* including design, engineering, ICT, technology education, and technical education. This explains, although not entirely, what is meant in the opening declaration that this book provides an effective encounter among the "what to do," "how to do it," and "why to do it." The changes in teaching technology and related demands at this time are daunting *and* extremely exciting! We have the same feelings about teaching technology that our students have about learning technology--excitement and trepidation.

As a text or reference book, a wide range of discourses, methods, and techniques are provided and explained in detail. Chapters can be read in any order and used in any combination. The theory emphasis will appeal to some while the practice emphasis appeals to others. The curricular focus will serve teachers at times while the instructional focus will be helpful at other times. For example, in Chapter III, in an advanced section on technology and ethics, moral philosophy used to provide a background to theories such as consequentialism. In the same chapter, instead of simply providing a functional section on how to develop skills, the psychology and sociology of skill acquisition are explained. This book is unique in its integration of mechanics (how to do it), pragmatics (what works), and ethics (what ought to be). This balance of the how, what, and why characterizes our mission as technology teachers.

Teaching Technology

The mere word "technology" provokes strong opinions and responses from the head, heart, hand, and feet. For some, the notion of technology produces fear and feelings of insecurity. Others feel power and security. Some feel excitement and others feel dread. Many stress out over the technologies they use. Similar emotions are provoked when most of us are forced to design something. Yet, this is what teaching technology is all about: excitement, dread, fears, hopes, insecurities, power, and intimidations. Teaching technology is about dealing with contradictions within technology itself. This is not an easy task. We have to know what design or technology is, or more specifically, what the *curriculum* of technology is, or ought to be. As well, we have to know how to teach technology, or more specifically, how to organize *instruction*. What should we learn? How should it be organized for teaching? More than questions of content and methods, these are the primary problems of C&I.

C&I are inseparable. One implies the other. We could say that C&I are dialectically related: when we study curriculum, we find instruction, and when we study instruction, we find curriculum. Why then, you might ask, do we have two concepts for what is virtually one process? Can we actually teach without content or methods? Can we learn to instruct or teach without learning the curriculum? Can we prepare to teach technology without preparing the curriculum of technology? And so it goes. As we prepare the curriculum of technology, we prepare how to teach technology.

This book proceeds with the premise that we learn to teach technology just as we learn to practice technology. We learn best and become professionals through reflective practice. Sections in the book will help you to stand back to reflect and examine practices while other parts will help you to actively experiment with the practices of teaching. Reflective practice requires a process of introspection into our identities, clarification of our values and discourses, candid analyses of the state of education and the world, and an externalization and internalization of what we have learned (Kolb, 1984; Schon, 1983, 1987; Waks, 2001). This book will help you clarify your identity as a teacher by connecting you with a wide range of dispositions, practices, and representations of practice in education. Reflective practice involves cycles of socialization, externalization, internalization, and identification (Figure 1). In the process of becoming a teacher, we initially connect and empathize with certain practices; ultimately, we articulate and embody the practices we identify with. Reflective practice simply means that we fluctuate between immersion and reflection. We practice, reflect, and re-evaluate our practice, and return to practice again. Teaching is a cycle of reflective practice.

This book encourages you to think of reflective practice as cyclical (Figure 2). Reflective practice begins with who you are, your identity, and life history, and extends

Figure 1. Cycle of Experience (Kolb, 1984)

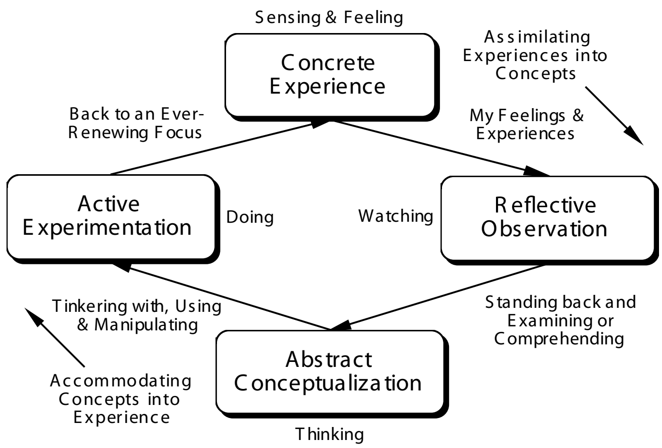
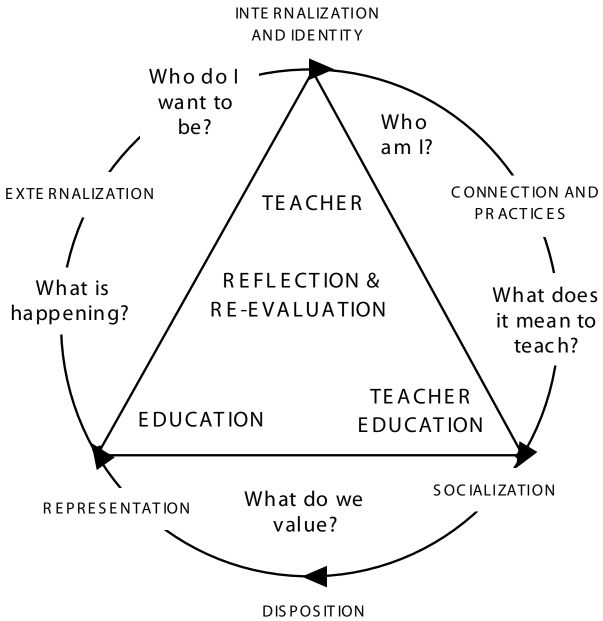


Figure 2. Reflective practice in teacher education



this knowledge to the meaning of teaching and teaching practices, to stories about teaching, to values and what is happening in education and the world. You have already generated a wealth of experience and knowledge, and the challenge is to help you focus this into the process of becoming a technology teacher. Empathize and identify with good practice, articulate this, and internalize what you learn. Reflective practice means that you think through and re-evaluate basic assumptions about education and technology.

Reflective practice also means that you pay attention to the difference between teacher education and school practices. We tend to overlook the difference between the way we are taught in teacher education and the way we teach in the schools. We develop assumptions about the symmetry of teacher education and school practices. For example, the technical component of teacher education is typically skills-based, justified by the notion that technology teachers should have a general breadth of skills and depth in one or two technical areas (e.g., ICT & graphic design). In most labs and workshops of teacher education, the focus is on skill development, whether it be problem or project driven. Pre-service teachers are often tempted to model this practice in the schools, overlooking the fact that the technical preparation of a technology teacher is designed to be different than the technical preparation of students in the school. The philosophies are different.

Reflective practice also means that we recognize that technology has ecological-natural, ethical-personal, existential-spiritual, socio-political, and technical-empirical dimensions (see Chapter VI). Whether we are learning to teach design, engineering, technology, or ICT, there are fundamental commonalties. By definition, design, engineering, ICT, and technology education *deals with knowledge in designing, creating, using, maintaining, managing, regulating, and recycling technologies (information, products, processes, and services).* This includes a concern for deliberately balancing the technical-empirical dimensions of technology, or technique, with its ecological-natural, ethical-personal, existential-spiritual, and socio-political dimensions. Another way of stating this is that we value and balance knowing, caring, feeling, and doing, or the head, heart, hand, and feet. We value learning *about, through,* and *for* technology. The mission of technology studies, from this perspective is to provide experiences for young people to develop and question feelings, knowledge, and skills that empower them to participate in all facets of technological endeavor--from the practical to the political. This means constructing and sustaining a vision for inclusion, ecological sensitivity, and justice for the common good in leisure and work. This mission means that we *demystify technology and its applications as well as resensitize students to the implications of their technological decisions and surroundings.* This means that we balance the head, heart, hand, and feet in our lessons, activities, projects, and courses.

To meet the mission of technology studies, we differentiate between small "t" or plural technologies and big "T" or singular Technology. We also stick to technologies that we use in the schools. Rather than overwhelming students with the impacts of big "T" Technology, we concentrate on the implications of the small "t" technologies that we use everyday in the laboratories and workshops. Think about a technology that you will be dealing with in the schools, such as a hammer, microprocessor, mp3 file, CAD application, or CNC router. Are you prepared to teach both the *applications* and *implications* of this technology? Can you demystify it and resensitize your students to its implications? Are you familiar with the history, politics, psychology, or sociology of this technology? Are you prepared to deal with ecological issues or the role of this technology in workplace innovation? How will you prepare resources that deal with the specific technologies? This book will play a significant role in assisting you to deal with the new challenges of technology studies.

Although we often organize schools as isolated rooms for disciplines or single subjects, subjects do not really exist in isolation. There are interconnections among the subjects. And although there is a hierarchy of subjects in the schools, all subjects have their place and reasons for existence. It is extremely important that technology teachers understand their role in the schools and the process of education. Technology teachers do not merely fulfill isolated roles and tasks. Technology labs and workshops are not merely places where technical skills are developed. Each day, technology studies plays a part in the whole development of students and their cognitive, emotional, physical lives. Whether it plays a role in their spiritual lives is dependent on how expansive technology interpreted in the schools. E-ligion and transcendental materialism are just two of the more recent ways in which technology, religion, and spirituality converge.

Organization of the Book

This preface provided an orientation to technology teacher education as well as the field of technology studies. A variety of positions on teacher education and technology studies were presented. These positions underwrite the remaining chapters in this book. C&I were described as interrelated practices that are fundamentally important in the process of learning to teach *about*, *through,* and *for* design and technology. The cycle of reflective practice was described as a framework for teacher education. The primary intention of this preface was to provide a broad picture of technology studies and inspire you to make commitments that will ground your philosophy. The secondary intention was to prepare you for the remaining sections of the book.

The book is organized into eleven chapters, a brief conclusion, and a glossary for definitions. Each chapter addresses distinct aspects of C&I for technology teachers, whether pre-service or in-service. Each offers something for both beginning teachers and those seeking professional development. Some are practice oriented (Chapters I-II), some are oriented toward theory (Chapters III, VI), and others are a blend of practice and theory (Chapters IV-V, VII-XI). The chapters are divided into sections with the last section containing activities for reflective practice and projection to the next phase or chapter. The last section defines technology studies and affiliated disciplines. Although the glossary is included as a reference, it is a good idea to consult this early on for definitions.

As indicated, the book moves from instruction to curriculum. *Advanced Teaching Methods for the Technology Classroom* is divided into three major sections, seen as follows.

Section I: Analyzing and Designing Technology-Based Instruction

Chapter I introduces communication and preparation for instruction. It begins with basic issues regarding effective teaching: communicating with confidence, preparing lesson plans, and addressing the full range (i.e., cognition, emotion, action) of objectives in the curriculum.

Chapter II continues with basic issues and focuses on organizing knowledge for instruction. It begins with theories of intelligence and explains the place of practical or procedural knowledge in these theories. Chapter II emphasizes the necessity of organizing knowledge, whether procedural or sociopolitical, for students. Advance organizers are crucial to learning about, through, and for technology.

Chapter III deals with the interrelationships among feelings, values, ethics, and skills. This chapter challenges conventional wisdom concerning skill acquisition in isolation of ethics, feelings, and values.

Chapter IV describes the relation between teaching methods and learning styles. This chapter identifies over fifty instructional and research methods for technology teachers.

Chapter V connects instructional methods to creativity, design, ingenuity, and problem-solving. Some technology educators argue that creative problem-solving and design are the essences of technology studies.

Section II: Analyzing and Designing Technology-Based Curriculum

Chapter VI deals with one of the most basic premises of technology studies, which is "doing leads to knowing." However, this chapter avoids the trap of cliché by exploring theories of learning and cognition. It is a theoretical chapter and serves as a transition from instruction to curriculum.

The final five chapters are oriented toward the content of technology studies and the challenges of assessment, classroom management, and safety.

Chapter VII provides ten significant justifications for technology studies, from technological literacy to gender equity to design and engineering.

Chapter VIII describes a comprehensive set of standards for the study of technology in the schools. These standards are extremely important, a point that cannot be over-exaggerated.

Chapter IX introduces strategies for instructional design and curriculum development. This includes basic principles as well as advanced techniques for organizing curriculum. This is the companion to Chapter II and the organization of instruction.

Section III: Implementing and Evaluating Curriculum and Instruction

Chapter X explains common approaches and philosophies of assessment and evaluation. This chapter offers details for both qualitative and quantitative assessment.

Chapter XI completes the textbook with an analysis of the challenges and difficulties of classroom management, facilities design, and safety. It can be reasonably argued that without adequate techniques for classroom management, C&I are hopeless. This final chapter concentrates on neglected aspects of technology teaching, such as equity and assistive technologies, legal dimensions of technology teaching, and ergonomics. The book ends by raising questions of class sizes and philosophical ideals for effective, safe practice in the schools. Technology teaching is exhilarating but it is also challenging. This book makes a point of both characteristics of this extremely rewarding area of teaching.

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My family and friends back in Pittsburgh (Go Steelers!) have been very supportive of my work in education and technology C. M. M. Peters deserves a special acknowledgment as well.

Dedication

To my mother, Helen Petrina,
and father, William M. Petrina

Section I

Analyzing and Designing Technology-Based Instruction

Chapter I

Communicating and Planning for Instruction

Introduction

A great irony in this age of information technologies is that communication skills for many people have atrophied. Students take low levels of communication and high levels of information overload for granted. This state of affairs has dire consequences for education, where clear, cogent communication is a prerequisite to learning. While it is tempting to "get with the times" by reducing communication to brief, sloppy exchanges, our challenge as teachers is to contradict these trends by modeling formal communication and information skills. This chapter begins with a description of an effective teacher to remind us that teaching involves a wide range of dispositions, knowledge, and skills. The remainder of the chapter focuses on demonstrations, lesson planning, and instructional objectives. Lesson plans and objectives are fundamental tools for demonstrating the applications, explanations, and implications of technologies to your students. Demonstrations are the single most effective method for technology teachers. Organization and communication are the keys to effective demonstrations.

The intent of this chapter is to provide you with the instructional tools that ground the practice of teaching technology studies. Communication, demonstrations, and lesson planning. These are the tools that will help you to immerse yourself in the craft of teaching. Recalling the model of reflective practice explained in the preface, this book takes the form of cycles that begin with you as a teacher. Over the first four chapters, you will be challenged to identify with certain instructional practices and techniques, and to choose among those with which you most identify. This chapter provides the tools for scaffolding a wide range of curriculum and instructional dispositions, knowledge, and skills. The operative word in this chapter is practice. Practice, practice, practice!

Characteristics of an Effective Teacher

A good teacher is a good person. Simple and true. A good teacher rather likes life, is reasonably at peace with her or himself, has a sense of humor, and enjoys other people. Among other things, a good teacher is good because s/he does not seem to be dominated by a narcissistic self which demands a spotlight, or a neurotic need for power and authority, or a host of anxieties and tremblings which reduce her/him from the leader of the class to its mechanic (Hamacheck, 1969, p. 343).

Dr. Donald Maley wrote one of the best descriptions of an effective technology teacher. After a life of work in technology education, Maley passed away in 1993. But his book titled "Identifying Skills and Attitudes Technology Educators Must Now Possess," is as timely today as it was when written in 1990. Maley (1990) described the cultural, social, and technological changes that were underway and anticipated responses technology teachers would have to make *if* they wanted to remain relevant in the new century. In the attitudinal or affective dimensions, the following are significant: Positive attitude to learning, faith in the intelligence of students, celebration of multiculturalism, respect for teaching as a profession, and ecological sensitivity in a world with finite resources. When Maley described an effective technology teacher, he included two skill dimensions to complement the attitudinal dimension. Teaching skills are those that normally come to mind when we think of C&I. For technology teaching, he included technical skills for demonstrations, design, and maintenance. The second group of skills is for personnel support and relate to skills necessary to manage classroom problems, resolve conflicts, and network outside of the school.

Malay's list is a complement to generic lists of what makes an effective teacher. Think about your teachers from the past. What qualities did they possess? What qualities should any teacher possess? Your teacher's characteristics will probably include what Maley suggested, and more. A good teacher expresses (Clark, 1988):

- Belief in and development of human capacities
- Awareness of one's vocation to become human

- An expanded social imagination
- New organizing ideas
- Deep sensitivity to tools in human relationships
- A learned immunity to technical goals
- Ability to make complex value choices
- Highly developed moral awareness
- Sophisticated information handling skills
- Expanded consciousness of the future

Our expanded notion of a technology teacher distills to some very basic fundamentals. Good technology teachers are effective communicators and are well prepared for the demonstrations and presentations they give. These are the fundamentals of teaching: Communication, preparation, demonstration, and presentation.

Communication

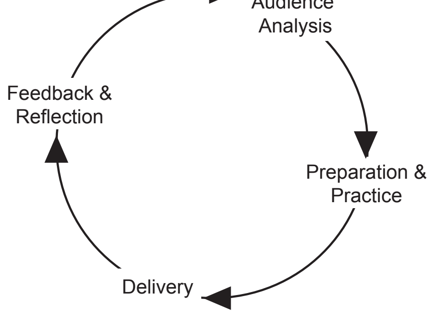
"Don't talk. Communicate" is a popular saying among communication specialists (Director of Navy Publications, 1980). This simple saying contradicts the common notion that talking and communicating are the same. Communication requires a conscious effort to effectively speak and listen. It requires a conscious effort on the part of all parties involved. *Casual communication* is part of everyday life, but in order for a teacher to exert an influence over students and motivate them for a chosen direction, communication must be formal. *Formal communication* assumes that there is information worth communicating and therefore is worth ensuring that this information is accurately received and understood. Ensuring that information is accurately received and understood is a complex challenge. Formal communication requires that the speaker have a high regard for accuracy, efficiency and precision. It is the speaker's (or sender's) responsibility to ensure that messages are clearly expressed and understood. Effective speaking—formal communication—is a unified act (Director of Navy Publications, 1980). One does not assemble separate techniques of emphasis, gesture, material, movement, vocabulary, vocal modulation, and teaching aids into adequate proportions for a perfect formula. Nevertheless, these individual facets of communication and others are important to consider. As a technology teacher, you ought to be able to give clear, accurate instruction, organize and give demonstrations, be a good listener, converse freely about plans and procedures, give adequate, ethical feedback, and deliver persuasive public presentations at meetings with administrators and parents.

Generally, there are six facets to the formal communication cycle: audience analysis, preparation, practice, delivery, feedback, and reflection. Each facet has several dimensions that, when addressed, make for effective formal communication. Whether it is a teacher demonstrating or presenting to a group of students, or an administrator presenting to a group of parents, these dimensions are important to consider. In most cases of formal communication, the presenter will know, ahead of time, at least a few characteristics of the intended audience. The grade level of the students or their general abilities, interests and expectations are characteristics that will allow the teacher to make some generalizations for preparing a lesson. Preparation involves selecting the content or information, synthesizing information into succinct points, designing a strategy for introducing the topic, developing an outline or plan and organizing necessary communications media and technologies. Practice means going over the lesson to iron out the flow and pacing, and to massage the lesson into an allotted time frame. Delivering the lesson involves proper dress and posture, configurations of the environment and students, vocal tone and confidence, eye contact, engagement with the students and an allowance for interruptions or feedback. Feedback can mean formative feedback that involves your own monitoring of the situation. Summative feedback refers to the time following your delivery, such as questions from the audience, feedback you give to the individuals following their questions, or any peer feedback that you may receive on the demonstration or presentation. Reflection will involve your analysis of the effectiveness of your demonstration or presentation and an internalization of commitments and revelations on improvement. Of course, reflection ends one cycle and begins another (Figure 1).

Audience Analysis

Formal communication begins with an analysis of the intended audience. Without actually surveying the audience for demographics and characteristics, or asking the

Figure 1. Cycle of reflection



audience what they know or want to know, we have to make assumptions. Teachers work in close proximity with their students day after day. This usually means that more informed assumptions are made than those by presenters who do not know their audience. In either case, informed assumptions have to be made. We can ask ourselves some general questions as we begin to prepare our demonstrations and presentations.

- How many students (people) will be present?
- What are the commonalties of their background, demographics (ability, age, class, gender, race, sexuality) and interests?
- What do they already know about the topic? What will they expect to learn?
- What other expectations might they have?

Preparation

Once we derive some fundamentals about our audience, we can begin to prepare a general outline or lesson plan. A standard lesson plan for technology studies is provided later in this chapter. Once the topic of the lesson is established, which for us is usually an application, device, instrument, tool, or machine, we decide on a central message. This is the focus or the organizing element for the ideas and information of the demonstration or presentation. The following criteria will help you to develop a good central message:

- What is *your* purpose? Is it to inform or educate, entertain, persuade, or stimulate action? Is the purpose to provide knowledge of a procedure? Or is it to provide knowledge of conditions?
- What are the objectives? What will the students learn by observing or participating in your demonstration or presentation? What direction or focus will you provide for their practice session or activity? Instructional objectives are described in the last section.
- Keep your message simple. If you cannot summarize a central message in one or two sentences, the topic is probably too expansive. Narrow the topic until you have a clear focus and purpose.

Once you have a focus, purpose, or objectives, decide on three to six key points that you want to emphasize. These may be nothing more than steps in a process. Develop a way to support each key point. You will want to include descriptive information, examples or brief stories. Develop a good introduction: How will you get the students' attention? What strategy will you use to introduce the topic? What sequence will you follow? What media will you need? How will you conclude?

Prioritize your information and make sure you are not going to overwhelm your audience with too much. Use this checklist to judge and prioritize what you want to say:

- What does my audience need to know?
- What is it that is nice for them to know?
- What is it that they really do not need to know?

Plan to use conversational language. Use contractions to make your language accessible. Avoid acronyms and jargon. Use short words and sentences, plus active verbs. Sentence fragments are typically ok, as this is how people talk. However, do *not* attempt to co-opt your students' language and jargon. Use sentences and phrases that people will remember and recall. Plan to repeat your main points. Do this throughout your lesson and again at the end. Use examples from your experience, illustrations, comparisons, contrasts, quotes, statistics, and anything to help your audience grasp what you are saying.

If you are preparing to give a lesson to students as opposed to a formal presentation, plan to ask plenty of questions! Ask a range of redundant questions and more challenging, high-level questions. Questioning is an effective way to maintain the attention of your audience. Generate four questions you would most like to be asked and the four questions you fear the most. Then prepare answers to those eight questions.

Develop an effective closure: Be sure to bring closure to your demonstration and presentation. You may want to simply reiterate your central message, purpose, or objectives. Use a short story related to the message or ask a final question. Comment on what comes next. The purpose of a formal communication is to move your audience to action or understanding.

How much of what you will say do you want to type out? Many teachers and presenters use note cards filled with key points instead of typed pages. If you are giving a demonstration, it is a good idea to use your lesson plan when you deliver the lesson. Overhead transparencies or Microsoft PowerPoint slides serve as effective cues. With anything that you will be reading, use 16-20 pt text and double space. Do not staple pages together and number the pages. Use your visual aids effectively. Research shows retention of information presented with visual support is 65% after five days, compared with only 5% without. But do not allow your visuals to become a crutch. Your visuals must be sharp as described in another section. Remember, your visuals are you—your technologies reflect your professionalism. There is one formula to keep in mind:

Respect & Status = (Image x 25%) + (Capability x 50%) + (Finesse x 25%)

Practice

Once you have completed the first draft of your lesson plan or presentation outline, walk yourself through it. Do a trial run in your head following the outline. This will allow you to make revisions and refine the outline or lesson. Practice the lesson or presentation at least once before you deliver it. Rehearse your delivery in front of a mirror if you can, or speak into a tape recorder. Stand up and visualize the audience in front of you. It is a good idea to do a lab or room analysis. If possible, go to the lab or room where your lesson or presentation will be given in advance to help eliminate surprises. Is the room arranged, as you want? Are the media, materials, and technologies available?

Delivery

Prior to the delivery of your lesson or presentation, you will probably feel nervous and anxious. This is normal: Do *not* panic! Even the most seasoned of teachers feel jitters prior to their lesson, the degree depends on the audience. There are techniques that help to relive nervous tension. Of course, the better prepared you are, the more confident and less nervous you will feel. Stretching your joints will relieve nervous tension that builds up immediately prior to the demonstration or presentation. Flexing your hands and taking deep breaths are good ways to settle your nerves. Clearing your throat will do the same. Use the adrenalin you have generated to get off to a good start, but be careful you do not go too fast. The more you speak in class or in public, the less stressful the experience will be.

Dress appropriately and wear something comfortable and conservative. Avoid bright white shirts, big jewelry, and brass buttons, any of which will be a distraction. Always look professional, even in a laboratory or workshop. Arrive early to prepare your media and any teaching aids that you need. If anything needs to be written on the board, make sure to di it ahead of time. If you are using computers, make sure the proper software is booted and ready to use. If you are using other technologies (devices, machines, or tools), make sure are they set-up, useable, and ready.

Once you are prepared, or once it is time, get your audience's attention. Make an immediate connection with the audience by appearing prepared and sincere. *Greet the audience*. Provide a proper introduction to the lesson or strategy. Introduce the purpose and an indication of what the demonstration is about or what you hope to accomplish. Describe the sequence of your demonstration or presentation (First I will…, second I will…, and then…). Tell the audience what you will say, how you plan to say it, and how long you the presentation will take. Use a watch or alarm to stay on time. Note the time and stay conscious of the time.

Stand tall and *take deep breaths*. Move when you can and remember that too much movement is distracting. Don't grow roots however! Maintain eye contact with your audience. Move your gaze around the room, fixing on different students to make a point. *Vary your tone* of voice (this takes practice) and rate of delivery. Show emotion and enthusiasm for your topic with your voice. Strike a balance: Don't speak too quietly, too loudly, too slowly, or too quickly. We all use verbal fillers such as "um," "uh," and "you know," but try to get in the habit of pausing silently instead. Use gestures and facial expressions effectively, but be careful not to overdo it. Smile when appropriate, but do not treat formal communication as a joking matter. Use hand gestures when appropriate. Between gestures, rest hands at your sides or lightly on a table.

Always use inclusive language, whether groups are represented or not. In formal communication, you must model respect. Avoid the mistake that if you say men, you mean all people, or if you say him, you mean her. Avoid exclusive language such as craftsman, fisherman, or repairman. Instead, use artisan, angler, mechanic, or technician. There are always options. When in doubt, consult the *Guide to Non-Sexist Language*. *Ask plenty of questions* if you are demonstrating to students and be prepared to address questions. Decide ahead of time whether you will field questions during your demonstration. On most occasions, it is best to defer uninvited questions and interruptions until you are finished. Keep your answers to questions short and to the point: do not ramble. Be honest—if you do not know the answer to a question, say so.

Most researchers indicate humor is the seventh sense necessary for effective formal communication. However, you will want to be careful with humor. Don't be a clown. Be cautious, as you can insult or hurt someone with even mildly offensive humor. Humor, used cautiously, will help you relax, will break down the rigidity of barriers between you and your audience, and will assist you in delivering sanctions and other necessary unpleasantries. Do not goof around with sensitive material!

Do not be apologetic with your material. If you have to apologize, either you did not prepare or the information you selected is not important. A mild apology may be in order if you ventured off topic. Conclude the demonstration or presentation with confidence and certainty. Review what you said, the central message, and the main points. Project what you demonstrated with what you or the students will be doing next. Close by letting the audience know that you appreciated their cooperation. Breathe a sigh of relief!

Feedback

In this section, we discuss the type of feedback you will want provide your students with during and following your demonstrations and presentations as well as the feedback you want to practice with your students on a daily basis. Respond positively to the questions and to appropriate behavior. Stay interested in the students' answers and to their questions. Sincerity goes a long way in demonstrations and presentations. In general, there are five guidelines for providing feedback:

- Focus on behaviors and questions, not personality.
- Focus on specific situations, not on abstract issues.
- Focus on the present.
- Attend to your students' receptivity to amount tone of the feedback.
- Make verbal and non-verbal messages congruent.

Remember, to provide feedback, you must observe and listen. Good listeners do not interrupt, especially to correct mistakes or make points. Good listeners do not make swift judgments and think before answering. Effective feedback and listening requires that you face your students and attend to the biases or values that distort what you hear. Look for the feelings and basic assumptions underlying actions, remarks, or questions. When giving feedback, concentrate on what is being said and refrain from rehearsing answers while you are listening. Feedback requires that you be judicial: do not insist on having the last word.

When giving feedback (Jung & associates, 1973), it is useful to describe the behaviors you observed along with the reactions they caused. If at all possible, make sure that the student is prepared to receive feedback. Avoid surprises. Your comments should describe, rather than merely interpret. Feedback should focus on recent events and actions or behaviors that can be changed. Effective teachers give plenty of positive feedback in a timely manner. Reserve extremely sensitive feedback for private meetings with your students and peers. Avoid anger or personal attacks and accept criticism of your own practices without becoming defensive.

There are four tried and proven techniques for giving feedback. One technique is paraphrasing. The real purpose of paraphrasing is not to clarify what the other person actually meant, but to demonstrate that you are actively listening. This typically means restating your student's original statement in more specific terms, using an example, or restating it in more general terms. Another technique is perception checking. Perception checking is a concerted effort to understand the feelings behind the actions and words. You may want to describe your impressions of your student's feelings on what he or she is dong. On the issue of skills for example, you may say: "I understand your resistance to this and see that you feel that you are not improving, but my impression is that there has been a lot of improvement in your skills." Avoid expressions of approval or disapproval. A third technique involves describing behavior. The most useful behavior description focuses on specific, observable actions without judgments. Avoid making accusations or generalizations about motives, attitudes, or personality traits.

The final technique is sandwiched feedback. The most effective and preferable feedback involves the sandwiching of constructive criticism between two positive, supportive comments. Sandwiched feedback focuses primarily on current behaviors and secondarily on products. For example, regarding the development of a Web page by your student, you might say: "I see that you have progressed from paper to screen on this project, but you are too impatient with the time necessary for neatness. Break this down into five steps and concentrate. Your enthusiasm is great and I know you can do a great job!"

Reflection

Reflection in the cycle of formal communication occurs quite naturally. We think about what we said, what we should have said, and what we should not have said or done. We think about our actions and feelings. We ask ourselves how our demonstration of presentation was received by our audience. Most of the time, we are our own harshest critics.

Intentional reflection typically involves providing ourselves with direction over time. The most effective way to engage in intentional reflection is through a review of a video recording of your demonstration or presentation. This requires that arrangements be made to tape your demonstrations or presentations with the intent of following up with analysis and reflection. In most cases of teacher education, video analysis is best done with peers. This allows for focused discussion on particular moments of the demonstrations or presentations. It may be easiest to begin your reflection by completing sentence stems:

- I learned that …
- I was startled by …
- I remembered to …
- I found it difficult to …
- I enjoyed …

- I plan to change …
- I anticipate that …

Reflection also involves a commitment to act on your realizations and resolutions. When beginning your teaching career, it is best to keep your commitments focused on specific abilities. Resolve to work on specific issues such as articulation, enthusiasm, facilitation, questioning technique, vocal pitch and volume, or conclusions. Practice the abilities you committed to in subsequent demonstrations. Another cycle is now completed and begun.

These techniques that promote reflection and the analysis of communication are included in what is generally called meta-communication. Meta-communication, somewhat like meta-cognition where we think how to think, is a practice where we communicate how we communicate.

Presentation Media and Communication Technology

Since the early 1980s, we have been witnessing a transformation in the technologies of communication. This transformation is captured in one word: Convergence. There has been a convergence of communication, media, and information technologies (computer, copier, fax, messaging, phone, printer, audio and video player, etc. convergences), modalities (image, print, sound, etc. convergences), practices (art, communication, design, fashion, film, marketing, programming, technology, etc. convergences) and corporate formations (cable and internet providers, music, newspaper, radio & television convergences). For the average teacher, convergence has been overwhelming. However, the average technology teacher welcomes the changes as new curriculum, practices, and topics of study.

In any communication process, there are transmitted messages through some imperfect medium toward some destination. The challenge is to minimize the noise, or distractions and interruptions in communication. The basic question, "Who says what, in which channel to whom with what effect?" is important to consider in any situation involving communication. Formal communication, often taking the form technical communication, depends on our consideration of this question (Shannon & Weaver, 1949).

Technical communication refers to a field concerned with how technical information is communicated and miscommunicated. There is a challenge in communicating knowledge in science and technology. On one hand, this knowledge can be complex and difficult to articulate. On the other hand, this knowledge often assumes a technologically literate audience, meaning that communication depends on a system of shared artifacts, signs, and signals. The level of understanding of these signs differs from situation to situation. To overcome these challenges, scientists and technologists resort to graphic and visual forms. Imagine the common set of directions for the assembly or use of a commercial product. Most written directions would be indecipherable without visual forms. Animations, charts, diagrams, drawings, figures, schematics, and tables are used liberally in technical communications. The new technologies or ICT have transformed the appearance of technical information, but basic principles of graphic design continue to underwrite the new visual aids.

Visual aids, when used properly, do not merely contribute to the communication content of demonstrations and presentations. They act as visual cues for you and can actually add credibility to your efforts. By definition, a visual aid is a form of graphic medium that aids the audience in understanding your material. An effective visual aid will reduce the time necessary to convey ideas and increase the understandability of the words being spoken.

Never use presentation media you haven't practiced with or checked to see how it projects. To assist your audience, visual aids should be clear, simple, legible, readable, and should express only one or two ideas. The presentation media should support what you say. Be sure to compensate with your voice to overcome your audience's divided attention. Face your audience, not your presentation media. Use media in a proper sequence: wait to display them until you are ready to talk about their content.

A sentence is readable when it is grammatically correct and flows without distracting words. Readability is an issue for handouts and books. Since visual aids use a minimum of words, they are more concerned with legibility. Legibility enables the audience to focus attention and register the point without mistake. The word *Yield* on a traffic sign is a good example of legibility. For overhead transparencies and Microsoft PowerPoint slides, the height to text should be 20-24 point, preferably in a sans-serif font such as Arial or Geneva.

Try to use key phrases and words rather than complete sentences. Overheads and slides should be understood at a glance, so eliminate clutter and unnecessary details. Most visual aids tend to be overly complex. Use a series of slides and transparencies as a solution. Be direct and simple with your visual aids. Be succinct.

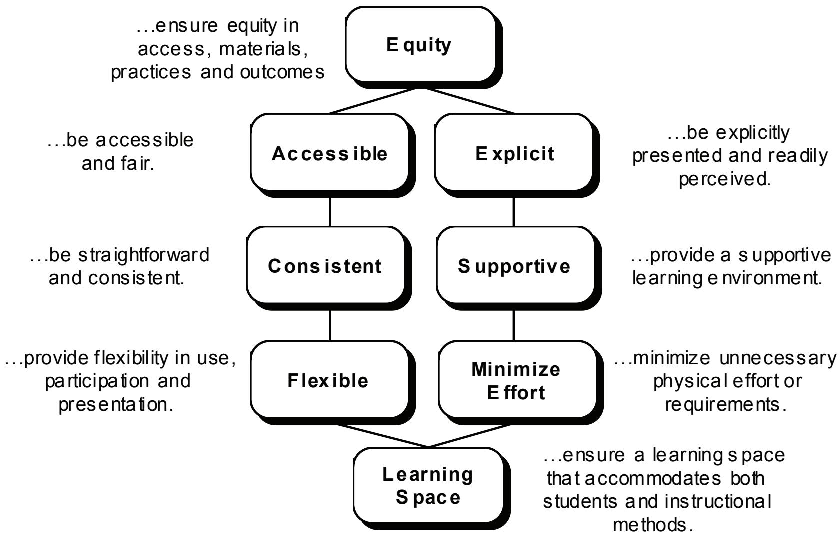
In schools, the most popular media for presenting continues to be overhead transparencies. However, with the reductions in prices of LCD projectors, digital media for presentations are increasing in popularity. For technology teachers, the issue can be one of sustainability. LCD projectors can significantly reduce transparency consumption. LCD projectors can be purchased with document cameras attached, which allows for the projection of 3D objects or sheets of paper placed on a table. The most common software for digital projections is Microsoft PowerPoint. If using

PowerPoint for Microsoft Windows, Appleworks for the Mac OS, or OpenOffice for Linux, attend to the same guidelines for other visual aids. Refrain from the bells and whistles that presentation software offers. Beginning teachers should adopt an application such as Microsoft PowerPoint for *all* of their overhead materials and presentations. In my experiences with new teachers, rarely is enough attention paid to teaching aids. Applications such as PowerPoint have templates that automatically contain the size of text and the amount of information that can be placed on a single slide. These are very helpful constraints for beginning teachers.

Your presentation media, like your handouts, represent you. Every technology teacher should develop skills that will help present themselves as capable and sharp in communication and media. This means that you will have to have proficiencies in arrange of audio, database, graphic, and text technologies. The interrelations between knowledge and graphic media are addressed in the next chapter.

Instructional materials and activities should adhere to general principles of instructional design, such as accessibility and equity. As we proceed through our study of C&I, we will keep the eight principles in mind (Figure 2). These eight principles were adapted from the universal design of materials and activities at the University of Guelph (1995). In Chapter IX, we will deal with principles of instructional design in a more detailed way.

Figure 2. Instructional design principles (Adapted from University of Guelph, 1995)



Demonstrations

A demonstration is a teaching method for modeling knowledge and skills related to the effective use or operation of applications, experiments, tools, machines, instruments, and processes. First and foremost, the goal of a demonstration is to communicate and model how to do something and how to talk about the task or technology at hand. Hence, the demonstration must be clear and effective. The demonstrator must demystify the tool or process, explaining what is to be accomplished, what knowledge is applied and the roles of certain skills and senses. The demonstrator will, of course, demonstrate more than how to perform a task. The demonstrator will also model what he or she knows and the level of skills and safe practice attained. The necessity of a demonstration derives from the inadequacy of words to depict technological processes.

Demonstrations are used in a wide variety of disciplines including architecture, art, design, engineering, home economics, mathematics, science, and technology. Some of the best demonstrations can be found on the popular chefs' cooking shows on television. If you cannot demonstrate, you will not be an effective design and technology teacher. As a matter of fact, it is not easy to give an effective demonstration, whether it is a five minute or thirty minute demonstration. Practice is the operative word when it comes to demonstrations. Prepare to practice and perfect the art and science of demonstrations. It is as simple as that.

Demonstrations are typically planned and delivered according to a pre-established sequence. There is no universal sequence, however, there are components that can be found from demonstration to demonstration. The most common components are the following:

1. Introduction (What will be demonstrated?)
2. Relevance (Why demonstrate this?) (Use Questions, Story, Description, etc.)
3. Use of application, instrument, machine, process, or tool (How to effectively and safely do or use this?) (Actual execution of proposed process)
4. Conclusion (Recap—Summarize, What was covered—Where to go next?)

Demonstrations that have a different emphasis might involve a common fifth component:

- Context or implications: (personal, current concerns, historical, psychological, sociological, etc.)

Table 1. Sequencing

Sequence #1	Sequence #2	Sequence #3
• Introduction	• Introduction	• Introduction
• Relevance	• Relevance	• Relevance
• Use	• Operation—Parts	• Safety—Care
• Operation—Parts	• Safety—-Care	• Use
• Safety—Care	• Use	• Implications
• Implications	• Implications	• Operation—Parts
• Conclusion	• Conclusion	• Conclusion

Demonstrations specific to tools and machines typically involve a few more steps at some point in the sequence. For example, in the sequences common to demonstrations of instruments, tools or machines, the steps previously listed are found, but in different parts of the sequence. There is not a correct sequence. Even for the same application of a process, software, or a tool, sequence #1 may work best on one day while sequence #3 works best on another day. The best advice is to experiment with sequencing. This requires you to play close attention to the sequence of your demonstrations.

The best demonstrations are dependent on very basic communication and teaching skills, such as thorough planning, advanced organization, creative strategy, and effective communication. The most seasoned of demonstrators plan in advance, rehearse, and reflect. They experiment with a variety of techniques from demo to demo. They experiment with delivery, sequence, staging and strategy, and media. In technology studies, there is always the opportunity to integrate the technologies with other subjects. When integrating, your task is to demonstrate the underlying principles of the technologies of interest. For example, it may be important to demonstrate the concept of lift and the underlying Bernoulli principle. You will have demonstrated the application as well as the explanation. For relevance, you will have to demonstrate the implications as well.

The key for the demonstrator is staying organized! If you are well organized, your audience, the students, will cue into the finer points of what you demonstrate rather than focusing on what is disordered. It is as important to organize the materials you need for the demonstration as the knowledge you will demonstrate. Pre-organize procedural and conditional knowledge on your lesson plan. Organize procedural knowledge for students by listing procedures on an OH transparency or the chalkboard. List new terms and safety procedures.

Empathize with your audience. Work from the level of the students to new levels, from their comfort zones to an expanded zone. Assume an intelligent, but inexperienced audience for your demonstrations. This means that you will have to be extremely clear about basic things. This means you have to communicate. Be certain of factual information and keep it simple. Use proper terminology. Use multiple teaching aids

Table 2. Examples of sequences for integration

Sequence #1	Sequence #2
1. Introduction/Review	1. Introduction/Review
2. Application	2. Application
3. Implications	3. Explanation (Relevance)
4. Explanation (Relevance)	4. Relations (Content)
5. Relations (Content)	5. Implications
6. Conclusion	6. Conclusion

and multimedia. Props and models work well in addition to OH transparencies. Providing information, procedure, and safety sheets for handouts to supplement the demonstration is usually necessary. Most successful demonstrators prefer to pass handouts around, or models, before or after the lesson.

Use the technologies that you are demonstrating. Rarely, if ever, should you attempt to demonstrate a technology that is not available to you or your students. You should always actually *use or apply* the technology that you are demonstrating. In other words, do *not* deliver a demonstration without having used the tool or material that you are demonstrating! Models or simulations of the technologies you are demonstrating are perfectly acceptable proxies. Work from the objects or technologies through principles (explanations) and back to the technologies (applications). Demystify the technologies—In language, application, explanation, and implication.

Ask plenty of questions during the demonstration—From redundant to more challenging, high-level questions. Questioning is the best way to maintain the attention of your audience. Respond positively to the questions. Stay interested in the students' answers and to their questions. Sincerity goes a long way in demonstrations. Use volunteers when possible in order to involve the students. But always demonstrate *before* asking a student to demonstrate. There is no advantage to either endangering

Table 3. Guiding principles for demonstrations (Vaughn & Mays, 1924, p. 93-98)

1. The demonstration should be timed as to meet the immediate needs of the class with the work at hand.
2. The demonstration must present a single fundamental use, procedure or general fact (should leave a single strong, indelible impression in the minds of the students).
3. The demonstration must be brief.
4. The work of the demonstration must be creatively and skillfully done.
5. The whole performance must be accompanied by concise and discriminating questioning and by a clear, accurate statement or discussion of the vital points involved in the demonstration.
6. The demonstration and accompanying questions must not be confused by discussions of various related matters. Do not confuse the demonstration with subsequent discussions of details or content.

or embarrassing a student. Remember, you can easily be upstaged by a participant so approach your audience with a bit of humility. You will invariably make mistakes. In most occasions, it is not worth trying to cover-up your mistakes. Try to play with mistakes if possible.

Lesson Plans

In lesson *planning*, the emphasis is on the second term: planning or preparation. A lesson plan that is not used or usable is a useless lesson plan. There is no single, universal format for a lesson plan. There will be some common elements, but for the most part, teachers customize from a number of different formats. In technology studies, we use a format that supports demonstrations, yet is comprehensive enough for discussions and group or individual activities. The lesson plan is comprehensive in that it involves all major components of a demonstration and ought to contain enough information to deliver a range of lessons, from six minutes to thirty minutes. A lesson plan is not a day planner or a week planer. It is not a unit plan or activity. It is a plan for a lesson, a framework for a demonstration, quite detailed in places.

Lesson plans are essential to demonstrations and provide a reference during the demonstration. In other words, lesson plans are used, handled during demonstrations. They are used as checks on our memory as well as guides to the process of the demonstration or lesson. Get in the habit of glancing at your lesson plan during your demonstrations. Check to see if you have sufficiently addressed what you wanted. For demonstrations where chemicals, electricity, tools, or machines are involved, the lesson plan serves as a legal document. This suggests the seriousness of planning and preparation. If you prepared a lesson plan but failed to cover crucial points, you can be held accountable if an injury were to occur. Design and technology lesson plans have the components listed below, but that does not mean that each lesson or demonstration will have all of these components:

TITLE

1. **Introduction:** Explain a bit about the technology to be demonstrated.
2. **Goals and objectives with major messages:** List the overall goal of the lesson. Also list at least three objectives, one from each domain (doing, feeling, knowing): The students will demonstrate the ability to....
3. **Lesson strategy:** Describe what you will do to get and hold the students' attention and to introduce the technology of interest.

4. **Instructional materials:** List the necessary teaching materials.
5. **Tools and materials:** List the materials and tools needed.
6. **Procedure:** How much time will you spend on individual parts of the lesson? This is the most important section. List the steps necessary for using or applying the tool or process. These details will prompt you to be clear and comprehensive.
7. **Assessment:** Describe the assessment strategy that you will use during or after the activity or practice session that will follow the demonstration.
8. **Special safety:** List any special safety precautions.
9. **Integration:** List subjects or topics with which this technology integrates.
10. **Implications (ecological or social context):** Describe relevant ecological or social implications regarding this technology.
11. **New terms:** List and define new terms.
12. **Questions:** List three questions that you might use during the lesson or on a quiz at some point.
13. **Summary:** Summarize the lesson or demonstration.

The key to lesson planning is to design and create the plan as comprehensively as possible. From each lesson plan, you ought to be able to give any number of demonstrations. For one purpose you may give a six-minute demonstration and for another purpose a fifteen-minute demonstration from the same lesson plan. DO NOT create a lesson plan that is merely applicable for a five-minute demonstration and another that is merely applicable to a twenty-minute demonstration. Similarly, you may use the same lesson plan for any number of emphases. Using the micrometer as an example, on one day you may demonstrate how to use the micrometer. On the next day you may review how to read the micrometer and emphasize the mathematical and scientific principles underlying the operation of the micrometer and precision measuring instruments in general. In the first demonstration you emphasized use. In the second you integrated math, science and technology. In a third demonstration you may emphasize the social implications of precision measurement and interchangeable parts or mass production. The point is that three lesson plans were not created. Rather, one fairly comprehensive lesson plan was created. Each lesson may be supplemented with handouts such as information sheets (what and why of the technology) and procedure sheets (how of the technology). So, you will not get into everything during a single demonstration, but your lesson plan prepares you to eventually cover a range of topics through a range of teaching methods.

Instructional Objectives

While not all goals and objectives can be planed ahead, lesson plans are likely to be much more effective when teachers value the notion of stating instructional objectives in specific terms. Additionally, objectives are likely to be much more effective if teachers conceptualize what students might and *ought* to know, feel, and do at the end of a lesson rather than the beginning. Objectives are intentions and hopes—students may actually do and feel exactly the opposite of what a teacher intended. But, if you decide in advance what you want your students to know, feel or do, or how you want them to act or behave, you can develop lessons that lead to intended results. Your assessment techniques ought to help you to determine if the results were achieved, and the nature of both intended and unintended consequences and results.

Knowledge does not exist independent of feelings or physical skills. Our emotions and skills cannot be separated from our capacity to learn and to act thoughtfully. With this in mind, all of our lessons touch the whole student; our practices are en-active, embodied, or experienced. What we say, what we do and demonstrate, and the projects we assign, the classroom policies we develop and the tone we set effect cognition, emotion, and action. There are always intended and unintended effects. We nevertheless ought to try to maximize intended effects while minimizing unintended effects. We ought to be cognizant of intended as well as unintended effects. These assertions will be explained in more details in the next two chapters.

In a lesson plan for demonstrating a micrometer, the goal of the first demonstration that a teacher would give with this plan is stated as follows: "The overall goal is to acquaint the students with the micrometer." This is the general *goal* and *provides direction for the teacher*. Goals are general and typically communicate the overall intent of the lesson. The goal is quite often communicated to the students. "Today is the first day of our orientation to precision measuring tools and I'm going to introduce the micrometer…" Objectives, on the other hand, provide specific intentions in three instructional domains (Cognitive or knowing, Psychomotor or doing, and Affective or caring and feeling). *Objectives refer to what the students will eventually know, do, or feel.* The objectives in the Micrometer lesson plan are stated as follows:

The students will demonstrate the ability to:

1. Identify two reasons for using the micrometer in metalworking and machining.
2. Properly adjust a micrometer and read measurements that are accurate to three decimal places (thousandths on an inch).
3. Handle and properly care for the tool and appreciate the tool as a precision instrument.

Objectives ought to be more or less formulated in assessable or demonstrable terms. In other words, the objectives provide direction for you to assess whether or not your students are learning what you intended. For the sake of brevity and clarity, we list only 3-4 objectives per lesson plan. Objective #1 deals with knowing. Objective #2 deals with doing. Objective #3 deals with feeling. We state objectives that derive from our basic philosophy of educating the head, heart, hand and feet. For each lesson plan, we ought to cover all three instructional domains with clear objectives. Remember, *goals* are what the teacher will be doing *during* the demonstration. *Objectives* are what the students ought to be doing, feeling or knowing at some point in time *after* the demonstration and after they had a chance to practice.

Instructional objectives help us to effectively plan for intended effects and keep us tuned into a wide range of aspects of human experience. Instructional objectives, for better or worse, have been divided into the three domains listed earlier. Note that a spiritual domain is uncommon in instructional practice, but ought to be considered

Table 4. Cognitive domain: Knowing (Adapted from Bloom et al., 1956; Hauenstein, 1972)

Knowledge: The remembering of learned material. This involves the recall of a range of material, from specific facts to complete theories, in an appropriate form.	Recognize, identify, notice, distinguish, aware, detect, locate, select, compare, adjust, listen
Comprehension: The ability to grasp meanings and understand. This may be demonstrated by translating one from to another (words to numbers), by interpreting material (explaining or summarizing), and by estimating future trends (predicting consequences or effects).	Identify, describe, compute, associate, position, sort, acknowledge, express, respond, select, convert
Application: The ability to use knowledge in new and concrete situations. This may involve the applicatin of concepts, laws, methods, procedures, principles, and theories	Change, demonstrate, discover, modify, operate, predict, prepare, solve
Analysis: The ability to break down knowledge into component parts so that its original structure may be understood. This may include the identification of parts, analysis of the relationship between parts, and the recognition of organizational principles involved.	Diagram, discriminate, distinguish, infer, outline, relate, separate
Synthesis: The ability to combine parts to form a new, original entity. This may involve the production of a unique communication (theme or speech), a plan of operations (intervention or management structure), or set of concrete relations	Categorise, combine, create, devise, design, generate, plan, reconstruct, rearrange, revise, explain
Evaluation: The ability to judge the value of knowledge, material or designs. The judgement are to based on definite criteria. These may be internal criteria (organization) or eternal criteria (ethics, relevance)	Appraise, control, compare, criticise, justify, interpret, discriminate, contrast

with certain demonstrations and lessons. When established in the 1950s, 1960s, and 1970s, the *Cognitive, Psychomotor, and Affective domains* focused on specific behavioral objectives—what students knew, did, or felt had to be observable and measurable. We have receded from these militant criteria, but we still plan with specific objectives derived from these three domains. In the best scenarios of teaching, we have shifted from militant analyses and one best way of thinking, feeling, and acting to pluralism—the recognition of a range of expressions of cognition, emotion, and action. We will elaborate on this in the next two chapters.

The *cognitive domain* (Table 4) refers to the recall or recognition of knowledge and intellectual abilities and skills. The *affective domain* (Table 5) refers to changes in appreciations, attitudes, emotions, interests, and values. The *psychomotor domain* refers to the development of manipulative, sensory and motor skills (Table 6). In *A Conceptual Framework for Educational Objectives*, Hauenstein (1998) provides a very useful synthesis of these domains.

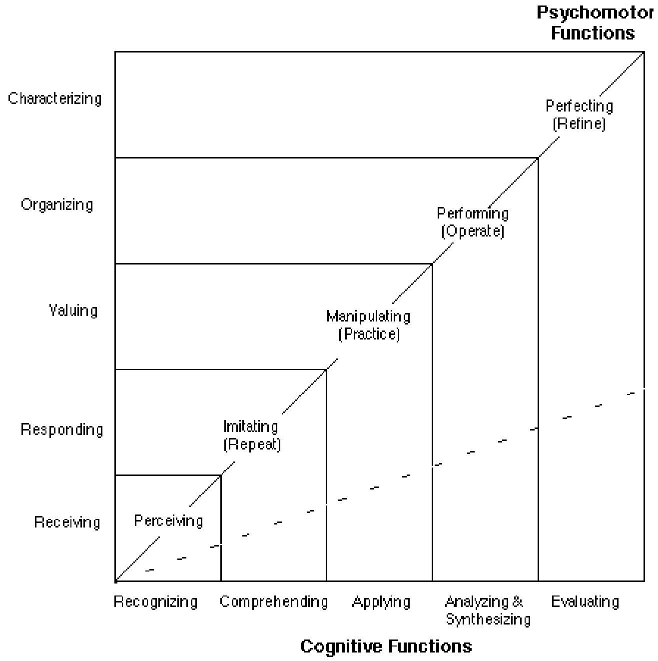
Table 5. Affective domain: Feeling (Adapted from Krathwohl, Bloom, & Masia, 1964; Hauenstein, 1972)

Receiving: Attention to particular phenomena or stimuli (activities, textbook, music, etc.). Attention ranges from simple awareness to selective attention	Ask, attend, choose, reply, recieve, recognise
Responding: Active participation that involves attention (receiving) and reaction. Acquiescence in responding, willing attitude, and a display of satisfaction or dissatisfaction. Interest and emotion is exhibited.	Behave, comply, cooperate, examine, obey, respond, observe, appreciate
Valuing: Worth or value attached to objects, people, or processes. Ranges from acceptance of valuve to complex levels of emotional commitment and responsibility toward values. Valuing is based on the internalisation of a set of specific values and the actualisation of these values in overt behavior. Behavior and emotions are consistent with values	Accept, balance, believe, defend, devote, influence, prefer, express, seek, value
Organization: Convergence of different values, resolution of value conflicts, and internally consistent value system. Emphasis on comparing, relating, and synthesis values. Individual is able to articulate how emotions and values are conceptualised and organized into value systems	Codify, commit, discriminate, favour, judge, order, organise, weigh, systematise, exhibit
Characterization: Individual has articulated a value system that has informed actions and emotions for periods sufficient to the development of a lifestyle. Behavior is consistent, value-driven, pervasive and predictable. Emotional patterns are mature and reflective. Individual is in touch with feelings	Internalize, verify, live according to

Table 6. Psychomotor domain: Doing

Observing: The act of recieving ad recognizing certain particular stimuli or phenomena (watching a demonstration, listening). Generally passive activity but with the senses responsive to stimuli. Involves the sensory reception of stimuli. Awareness of objects and relationships. Infers recognition and awareness. Tends to build sensory awareness.	Distinguish, hear, see, smell, taste, touch
Imitating: The act of interpreting, translating and responding to repeat or stimulate an act in accordance with stimuli or phenomena (repeating word pronunciation, assuming a physical position, usina a tool as shown). Dependent on the situation in which it was first encountered. Individual can display the sensory and motor actions necessary to repeat and act. Guided response through imitation and trial and error performance. Infers comprehension and responsiveness or basic interest. Tends to build skill conformity.	React, focus, adjust, imitate, copy, position, prepare, approach
Manipulating: The act of valuing and applying knowledge to perform an action in an situation analogous or similar to that which it was originally imitated. Application of knowledge to similar situations (solving a new problem, trying out a new solution	Simulate, duplicate, copy, determine, repeat, reproduce, emulate, model, match, approximate, adapt, practice, manipulate
Performing: The act of analysisng, synthesizing and organizing actions to act rationally and functionally. Meeting situations with confidence and performing in a variety of situations dissimilar to those of manipulation. Intellect, emotions and skills are developed to the point of ownership. Analysing actions into parts to make new relatinships consistent with values. Automatic and habitual phase of motor skills; applies sensory and motor skills as a matter of habit and intent. Infers analysis, synthesis and the organization of values	Assemble, calibrate, mold, set-up, maintain, operate, alter, retrofit, re-set, standardise, simlify, convert, order, correct
Perfecting: The act of evaluating and behaving with a high degree of sensory and motor skills, sensitivity, expertise and artistry. Highly independent activity seeking to creatively apply knowledge and skills. Understanding and control of knowledge, emotions and skills to achieve sophisticated levels of being. Internalisation of knowledge is reflected in character and lifestyles. Judgements and decisions are consistent with values and knowledge. Infers evaluation and characterization. Tends to exhibit high level capabilities	Coordinate, integrate, regulate, design, devise, develope, originate, invent, formulate, automate

Figure 3. Domain vectors (Adapted from Hauenstein, 1972)



Functional Relationships Between Affective, Cognitive, and Psychomotor Development

Humans do not merely act but act in accordance with their emotions and intellect. The psychomotor vector will fluctuate toward the affective or cognitive axis in relation to the forces associated with the learner's emotional and cognitive development. We do not develop in a balance of emotions, knowledge, and physical skills. Some of us will attain high levels of physical skills but low levels of emotional development. Similarly, others will develop high levels of knowledge and emotional sensitivity but will attain a low level of physical dexterity. The challenge for teachers is to attend to whole development and help students attain a balance of cognitive, emotional, and psychomotor development (Hauenstein, 1998, p. 101-108) (Figure 3).

In Chapters III, VI, and VII, these interrelationships among cognition, emotion, and action are explored in detail. The three domains of learning presented in this chapter are by no means exhaustive. For example, critics point out the failure of the three conventional domains to capture the spiritual dimension of learning. Although these domains provide developmental models that facilitate instruction, they are not nuanced enough to address technology. In Chapter III, a developmental model of skill acquisition is presented and Chapter VI contains an explanation of how we learn technology within a range of developmental models. Chapter VII provides developmental models of technological literacy or technology domains.

Projection and Reflective Practice

The intent of this chapter was to explain the fundamental issues of communicating and organizing for instruction. We concluded that effective instruction requires effective communication and organization. Teachers organize themselves through lesson plans and instructional objectives. The affective, cognitive, and psychomotor domains help us to create instructional objectives and maintain a balanced view of the educational process. The following two chapters address knowledge, feelings and skills, and their relations to the three domains.

This chapter is incomplete until you participate by designing a demonstration, creating a lesson plan, and delivering the demonstration before a peer audience and video camera. This is called microteaching. Using lesson plans developed in your course, you ought to prepare and deliver two-three demonstrations similar to those you will be delivering in your laboratories and workshops in the schools. In this way, you will learn how to present the content you developed. Through the benefits of peer and instructor feedback following the microteaching sessions, you can assess your presentation skills, use of teaching aids and multimedia production, voice and articulation, questioning and feedback style. You will receive the benefits of practice in providing and receiving feedback and critique, and with the benefits of videotapes, you can effectively reflect on your strengths and challenges, and hone in on areas for potential improvement. Reflection on the process of demonstrating provides a context in which to think about your practice in ways that you may not have previously considered. Microteaching allows you to integrate theory with practice, technical applications with environmental and social implications, and technical skills with considerations of gender, racial and special needs.

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Chapter II

Organizing Knowledge for Instruction

Introduction

What is intelligence? What do we know about knowledge? Are design and technological knowledge unique? Do different types of knowledge demand different organizations? How can we employ cognitive skills in the resolution of technological problems? This chapter provides an introduction to current theories of intelligence and knowledge with an emphasis on instructional organization. We will discuss learning theories and theories of cognition in Chapter VI. In the previous chapter, we acknowledged that despite the proliferation of communication and information technologies, communication skills for most people have atrophied. At the same time this proliferation of new technologies has created conditions for what we experience as information overload. For this reason, it is extremely important that teachers develop effective skills and techniques for the communication, organization, and presentation of information and knowledge. It is essential that teachers develop working understandings of current theories of knowledge and skills. Our understandings of technological knowledge and literacy along with the theories that we act on determine the way we teach about, through, and for design and technology. Current theories of intelligence, or cognitive pluralism, and the organization of knowledge are fundamental to effective instruction. This chapter builds on the basic communication and organization techniques provided in Chapter I. The effective organization of instruction requires the effective organization of knowledge.

Intelligence

Intelligence is no longer merely associated with the reasoning skills necessary to successfully complete an intelligence test. The twentieth century began with very narrow notions of intelligence that differentiated among people in extremely biased ways. According to Binet-Simon intelligence exams, students were found to be imbeciles, morons, retarded, sub-normal, normal, or geniuses according to their intelligent quotient or IQ. Even while scientists argued that intelligence, or a "general mental adaptability to new problems and conditions of life," was both innate and environmental, most of the scientists leaned toward the genetic side rather than the cultural side. Not very surprisingly, many students from poor and working class families were below average intelligence. Students found to be below average intelligence were believed to be stupid for life. By the 1960s however, both the exams and the scientists were found to be racially biased. One result of research into intelligence practices was that intelligence is no longer measured in terms of exams and IQs. Fairly recent changes in cognitive science have led researchers to re-think customary notions. In effect, intelligence has been democratized. Everyone is intelligent in some way. Intelligence can generally be defined today as "the capacity to solve problems or to fashion products that are valued in one or more cultural settings" (Gardner & Hatch, 1989). The difference between this and earlier definitions is the qualification that connects intelligence to specific cultural settings. Intelligence theories continue to suggest that intelligence results from an interaction of biological and cultural forces and functions.

According to Howard Gardner (1983, 1993), each and every human has the capacity to be intelligent in one or a number of eight areas that correspond with ways of resolving problems. Multiple intelligence involves nine capacities: bodily-kinesthetic, existential, interpersonal, intrapersonal, musical, logical-mathematical, linguistic, naturalist, and spatial. Most of us in technology directly involve bodily-kinesthetic, logical-mathematical, and spatial capacities in very complex ways. You could say that we have developed high levels of intelligence; we have high levels of bodily-kinesthetic, logical-mathematical, and spatial intelligence. This is not to say that these three intelligences are the only significant intelligences for practice in design and technology. In fact, teaching typically requires high levels of existential, interpersonal, and intrapersonal intelligence, or as we will explain in the next chapter, high levels of emotional intelligence. When we are creative, as we will discuss in Chapter V, we integrate a wide range of intelligences to the resolution of problems.

Why should we consider Gardner's theory of multiple intelligences (MI) to be a breakthrough? Is it a tenable theory? Does it resonate with your own experiences? One of the primary reasons MI is such a breakthrough is that it validates practice in design and technology. MI puts the ball back into the central offices of schools and governments. No longer is it sufficient to provide for merely one or two intelligences

Table 1. Gardner's multiple intelligences

Bodily kinesthetic intelligence: The ability to use mental abilities to coordinate one's own or others' physical movements.
Existential intelligence: The ability to explore philosophical dimensions of being, existence, and meaning.
Interpersonal intelligence: The ability to communicate and converse with others on social terms. Expressive or persuasive articulation and communication of insights and thoughts.
Intrapersonal intelligence: The introspective ability understand one's own feelings and motivations. Expressive articulation and communication of feelings.
Linguistic intelligence: The ability to effectively manipulate language to express oneself rhetorically or poetically. Use of language and narrative as a means to the memory of information.
Logical/mathematical intelligence: The ability to detect patterns, reason deductively, and think logically. Often associated with math, science, and technology.
Musical intelligence: The ability to recognize and compose musical pitches, rhythms, and tones. (Auditory functions are necessary for pitch and tone but not necessarily for rhythm).
Naturalist intelligence: The ability to sense natural cycles and rhythms and to relate to the natural world. The ability to discriminate among (animals, plants) as well as sensitivity to features of the natural world (clouds, cycles). Sensitivity to natural processes.
Spatial intelligence: The ability to create and manipulate mental images to find and solve problems. Not necessarily limited to visual domains.

in schools. No longer is it sufficient to orient an entire educational system toward one or two intelligences. The pressure is now on the schools to accommodate and nurture a range of intelligences that were previously neglected or ignored. MI also makes a case for attending to a range of learning styles in the schools. Students learn differently, as we will explain in a later chapter.

The trend in intelligence theory is toward cognitive pluralism, or the recognition of a wide range of expressions of knowledge. Cognitive pluralists, such as Gardner and Robert Sternberg (1985), recognize that our traditional observations of intelligence were quite limited. Pluralists theorize an inclusive range of expressions of intelligence that recognize the ways that the head, heart, hand and feet are "intelligent" and learn together. If cognitive pluralism recognizes multiple ways of knowing, then emotional pluralism recognizes different ways of feeling and kinesthetic pluralism embraces ways of moving to express skill. In Chapters III and VI, we will explore cognition, emotion, and action in more depth.

Like Gardner, Sternberg revised traditional notions of intelligence by arguing that there were multiple intelligences. Sternberg also responded to Gardner and argued

Table 2. Sternberg's triarchic theory of intelligence

Analytical intelligence: How individuals relate to their internal worlds; Analogic problem-solving.
Creative intelligence: Insight, synthesis, and the ability to react to novel stimuli and situations.
Practical intelligence: Ability to grasp, and solve real-life problems in the everyday jungle of existence.

that seven (there are now nine) intelligences were too many and weakened the very notion of intelligence. For Sternberg, there are three modes of intelligence that cover the spectrum of Gardner's MI. Sternberg's triarchic theory validates design and technology educators in the same way that MI does. The new theories of intelligence recognize the variability among populations and acknowledge the range of capacities that can be developed in education.

Knowledge

Our views of intelligence were changing at the same time that our views of knowledge were changing during the 1960s and 1970s. Current perspectives on knowledge helped us to dispense with the notion that knowledge is information, or an accumulated database that can be applied when the circumstance arises. Here, knowledge is passive and in storage for potential uses. Knowledge is much more dynamic, and generative rather than applicative. Knowledge generates action, and of course, action or experience generates knowledge. Knowledge is both the process and product of creative action. We will address learning theory and the generation of knowledge *per se* in Chapter VI. In this chapter, we stick with the issues of articulating and organizing knowledge for instruction. To make a transition in education from knowledge as information to be transmitted from teacher to students, to knowledge as dynamic, we have to understand the types of knowledge that are fundamental to technology studies. We have to understand how knowledge is articulated and integrated into experience.

In the first chapter, we introduced the cognitive domain, which is a model of how knowledge is articulated from basic memorization of information to the application and evaluation of knowledge. The lowest level of the cognitive domain involves rote and basic memorization and information. Knowledge is articulated here as simple bits of information. Knowledge is articulated at the next level as a translation of one form of facts to another. This requires comprehension. The third level involves the application of knowledge to concrete challenges. Knowledge is articulated at this level as laws, models, and procedures. The next two levels involve the analysis and synthesis of knowledge. Knowledge is articulated at these levels as theories, plans of action, designs, and inventions. At the highest level, we are able to pass judgment on the theories, plans of action, designs, and inventions articulated at the levels of analysis and synthesis. Knowledge is articulated at this level as schemes for evaluation and critiques.

Outline 1. Procedural and propositional knowledge of CAD

I. Introduction
  A. CAD
  B. Components of CAD systems
    1. Hardware
    2. Software
  C. Operating systems
  D. CAD user skills
  E. Data storage
  F. Data handling
II. CAD system interface
  A. Main menu
    1. Drawing editor
    2. Configuration
    3. Plotting
  B. Commands
    1. Drawing
    2. Tool
    3. Edit
    4. Set-up
    5. Block and attribute
  C. Prototype drawings
  D. Simple geometric shapes
    1. Entity creation
    2. Plotting
  E. 2D CAD
    1. Layers
    2. Dimensions
    3. Plotting with layers
III. Symbol libraries
  A. Access
  B. Organization
  C. Slides
IV. Database Management
  A. Integration with CAD
  B. Databases (Dbase, Excel, etc.)
V. 3D modeling
  A. Wireframes
  B. Extrusions
  C. Surfaces/meshes
  D. Solids
VI. Design and analysis

I. Product and Service Life Cycles
  A. Designing, engineering, and planning
    1. Data management
    2. CAD and DTP
    3. Parts acquisition
    4. Concurrent engineering design
  B. Developing and testing
  C. Producing
  D. Reintegrating, reconceptualising, recycling
  E. Constructive technology assessment
II. Economy, workforce, and workplace
  A. Workplaces (Structure, tasks, culture)
  B. Market trends and forces
  C. Opportunities
    1. Worker well-being
    2. Creativity and productivity
    3. Labor and management
III. Technology, people, and management
  A. Innovation in the factory and office
  B. Computers and automation
  C. Managerial innovation
  D. Organizational structures
IV. Managerial, user, and consumer decision makin
  A. Forecasted information
  B. Empirical information
  C. Experience
  D. Continuing education and training
V. Sociotechnical theory
  A. Sociotechnology and workplaces
  B. History of CAD in workplaces
  C. Sociology of CAD
  D. Psychology of CAD

Think about how loosely we qualify types of knowledge: *artistic* knowledge, *practical* knowledge, *scientific* knowledge, *tacit* knowledge, *technical* knowledge, and so on. Inquiring into types of knowledge involves the work of epistemology and praxiology. Read the definitions of terms related to knowledge. In design and technology, a wide range of different types of knowledge is used, as listed in the table below. In the next few sections, we will reduce the types of knowledge that we deal with to *propositional* and *procedural* knowledge. For all intents and purposes, procedural knowledge will refer to technical knowledge and procedural knowledge when added to propositional knowledge will refer to sociotechnical knowledge. We generally define procedural knowledge as knowledge of directions or procedures and propositional (or declarative) knowledge as knowledge of conditions. Both are necessary for design and technological practice.

Traditionally, technical knowledge is emphasized in design, engineering, ICT, and technology education and sociotechnical knowledge is ignored. Nevertheless, one of our responsibilities in the change from industrial education and educational technology to design and technology education is the incorporation of sociotechnical or procedural plus propositional knowledge into the curriculum. It is our responsibility to deal with the ethical-personal, ecological-natural, existential-spiritual, and socio-political dimensions of technology as well as with the traditional technical dimension.

Take computer-aided design (CAD) for instance (Petrina, 2003). A vast majority of instruction focuses on procedures or applications. Very little time is spent on conditions and implications of CAD. In the following outlines, procedural or technical knowledge is represented on the left and propositional knowledge on the right (Outline 1).

They reinforce each other. It is as important for a student to understand the ergonomics and psychology of CAD, as it is to understand how to create a wireframe model. Perhaps 60%-70% of time in technology studies labs and workshops ought to be spent on procedural knowledge and 30%-40% on propositional knowledge. More than anything else, this example lays out the argument for why technology studies teachers have to pay attention to both procedural and propositional knowledge and their relationships with reasoning abilities.

Cognitive Skills: Reasoning

Knowledge is articulated in various forms such as algorithms, concepts, directions, factlets, generalizations, and strategies. How are these forms developed? How do we develop a series of generalizations from disparate facts and concepts? How do we create and test facts? How do we develop rules of thumb and strategies from different sets of directions? This is where the cognitive skills and the processes of reasoning enter into intelligence. We have developed cognitive skills or reasoning techniques for generating and testing knowledge. Of course, reasoning does not account for the generation of all knowledge. For example, intuition and spiritual revelation offer us ways of generating knowledge without reason. Nevertheless, the development of reasoning abilities is essential to design and technology. In some cases, knowledge in design and technology, like scientific knowledge, is rational and verifiable. The results are predictable. In other cases and when extended to social situations, this knowledge can be unpredictable. In some cases, we want to solve problems, in other cases we want to create and find problems. Sometimes we want to analyze and sometimes we have to synthesize. Designers and technologists need a range of abilities and cognitive skills that allow them to reason and learn from mistakes and successes. Students and teachers of design and technology need these same abilities and skills.

At times, students should engage in convergent reasoning and other times divergent reasoning (Figure 1). Drawing conclusions, generalizations, and inferences is extremely important in design and technology but is also difficult. Drawing inferences and distinguishing commonalties from a range of different data involve the practice of convergent reasoning. Diversifying ideas and identifying differences from a range of data involve the practice of divergent reasoning. Both convergent and divergent reasoning have to be taught and practiced. Convergent reasoning often refers to synthesis while divergent reasoning refers to analysis. Activities such as brainstorming and sketching help students develop divergent reasoning skills. Choosing among alternatives and consolidating ideas into a single design help develop convergent

Figure 1. Cognitive skills

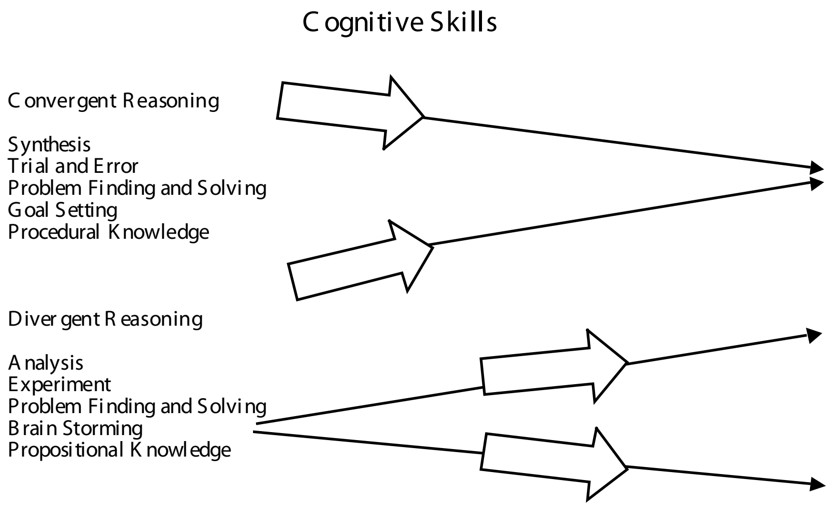
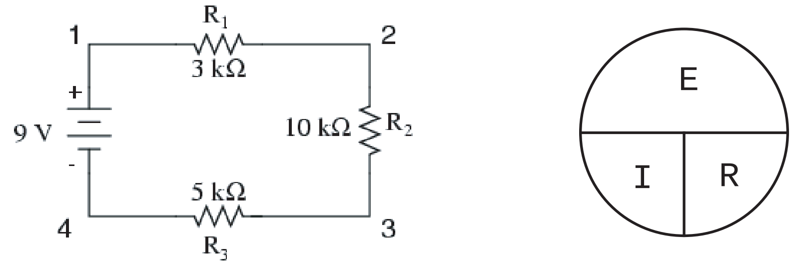


Figure 2. Ohm's Law and a Simple Series Circuit



reasoning skills. Although learning style research suggests that individuals have preferences for either convergent or divergent reasoning (see Chapter IV), technology requires that we develop skills for each. For instance, the ideation and problem finding processes of design requires that we diverge from initial ideas and the settling on a design requires that we converge on an eventual solution.

Deductive Reasoning

From generalizations to specifics. Deductive reasoning is the analogue of divergent reasoning. Typically associated with hypothesis testing in chemistry, engineering, or physics, deductive reasoning has many applications in everyday life and learning. For example, if a technician knows Ohm's Law or other electrical principles, he or she can deduce and isolate problems to specific components or parts of a circuit (Figure 2). We also deduce directions and procedures for working around electricity from our general knowledge of electrical danger related to shock.

Inductive Reasoning

From specifics to generalizations, inductive reasoning is the analogue of convergent reasoning. Typically associated with theory building in biological, earth, or social sciences, inductive reasoning has many applications in everyday life and learning. For example, if a tire manufacturer finds that in twenty isolated cases there were blowouts of tires at highway speeds, the manufacturer will generalize that there is likely to be more blowouts and recall that brand of tire. In much of technological practice, inductive reasoning deals in probabilities. Decisions are made based on the probability of this or that happening or being the case. Chances are taken based on calculations of probability. In the case of the tires, while twenty blowouts in 500,000 tires is a low percentage, the tire manufacturer would rather error on the side of caution than suffer a lawsuit.

Deductive and inductive reasoning have crucial applications in technology studies. For example, we may provide students with Ohm's Law and a circuit and ask them to test the relationships among current, resistance, and voltage. Or we may provide them with a number of circuits, but not Ohm's Law, and ask them to discover relationships among current, resistance, and voltage. In the first instance, deductive reasoning, we have organized knowledge for the students. We have given them the basic organizer of our knowledge of relationships among three primary forces of electricity. In the second instance, inductive reasoning, we are asking the students to organize knowledge of electricity. We gave them the components of a basic electrical system but not the organizer of the relationships among forces. Yet, in both cases, the result was the development of cognitive skills and organization of knowledge.

Articulating Knowledge

How do we articulate what we know and what we want students to know? How can we help students to articulate what they know? Procedural knowledge is typically articulated as directions, rules of thumb, and strategies. Propositional knowledge is typically articulated as facts, concepts, and generalizations. When we teach it is necessary to organize our knowledge. We must learn how to provide accurate and clear directions and how to describe the facts and concepts related to our topics. To be an effective teacher we must be articulate with knowledge of design and technology (McCormick, 2004).

Procedural Knowledge—Know How

Procedural knowledge is knowledge of procedures, dealing with episodic memory. For example, we remember the episode of scanning and recall the procedures to scan an image. The movement through procedural knowledge ought to be from directions to strategies. Procedural directions and order define procedural knowledge. We ought to help students develop algorithms or rules of thumb for strategies. For example, we provide specific procedural directions for students learning to use an electric drill. We then introduce another power tool, such as a sabre saw, and again provide specific directions. But we want students to develop rules of thumb for using power tools, such as do not make adjustments when the tool is plugged in. Or clamp materials in place when using power tools. And ultimately we want students to develop overall strategies for using power tools. We want them to develop a strategy for the entire set-up, use and clean-up. We can test algorithms and strategies with the details of directions. From algorithms we ought to develop strategies. A strategy is a general plan of action that ought to be flexible enough to guide a range of procedures. Strategies are a form of metacognition, reflecting an awareness of how one proceeds with procedural knowledge.

- **Directions:** How to do this?

- **Algorithms:** Rules of thumb established?

- **Strategies:** General plan of action established?

Procedural knowledge is typically organized as step-by-step directions, taking the form of step 1) do this, step 2) do this and so on. Procedures are basically if-then rules: If the condition specified is satisfied, then the next step in the action is carried out. In regards to safety procedures, if the conditions for safe use of a machine are satisfied, then the procedures for using the machine is implemented. For procedural knowledge to be learned, procedures must be rehearsed, both cognitively and physically. We also create procedural directions, guidelines and rules for completing tasks and procedures that take the form of "do this" but "do not do this." There is an explicit order to directions and, in most cases, steps cannot be substituted one for the other. In many cases, if we transpose steps, the process will fail and injury or harm may come to the student completing the procedure. Guidelines and rules cannot be crossed. Recall a time when you were given directions for finding your way to an unfamiliar location. With poor directions, you most likely got frustrated and lost; you probably asked for directions again. With clear, orderly directions you found your way. Procedural knowledge is basically analytical, linear, and future-oriented. Procedural directions are derived from task analyses of activity (Chapter VIII). In our case, directions are derived from a task analysis of technological activity.

Designers and technologists develop the habit of generalizing rules and steps into guidelines and rules of thumb. Over time and practice, directions and if-then rules become routine, habitual, and automatic. Here, we recognize a situation as typical and respond consistently according to an estimated probability that our response will satisfy the conditions of the situation. A rule of thumb is a shortcut that allows us to circumvent or integrate redundant steps. Rules of thumb eliminate options for us, and shortcut the process of eliminating the same options time and time again. For example, when auto technicians confront a car that is backfiring, they will shortcut a series of steps and zero in on the backfire as an ignition-timing problem. The student technician will develop this backfiring rule of thumb only after s/he has diagnosed a number of vehicles using the directions for diagnosing erratic and sluggish performance. Rules of thumb are organized as guidelines that take the form of "if this is the case, then do this." In other words, if we recognize a situation as this, then we ought to respond in this way. That expert technician will have a strategy, or organized rules of thumb, for trouble-shooting and maintaining sluggish vehicles or inoperative peripherals. Strategies anticipate what situations will be confronted and how these situations will be addressed. Strategies involve the organization of knowledge and resources for tackling a task or procedure, or in a word, metacognition.

In technology studies, our responsibility is to empower know-how, or procedural knowledge with propositional knowledge. Procedural knowledge ought to be used to inspire propositional knowledge. In Chapter VI, this premise of our learning theory is explained in detail. In the next section, we elaborate on propositional knowledge.

Propositional Knowledge—Know Why, What, When, Who, and Where

Propositional knowledge is knowledge of conditions and meaning, dealing with semantic memory. The movement through propositional knowledge ought to be from factoids or factlets to generalizations. Factlets are often infotrivia and somewhat useless without form or structure. We want students to organize facts and ultimately develop concepts and generalizations. A generalization is a synthesis of facts, concepts, and phenomena that derives its significance from a range of places and practices and has applications in many concrete situations. A concept is a mental image conveyed through language. Concepts are typically abstract, and are subject to the expansion of meaning and delineation of detail as experience provides new applications and different contexts. Concepts and generalizations can be tested with the details of factlets and facts.

- **Factlets:** Bits of information about this?
- **Organized Facts:** Information organized?
- **Concepts & Generalizations:** General relationships articulated?

Propositional knowledge typically takes the form of facts, concepts, and generalizations that have either a psychological or logical organization. Propositional knowledge ultimately deals with relationships. Propositional knowledge is typically organized by classification, chronology, and relationship. Picture a list of animals that has no order imposed upon it. We can derive order by organizing the list according to our values and preferences: animals we like and animals we dislike. This would be a psychological organization. Or we can derive order by alphabetizing the list, by classifying into classes such as amphibians or ranking according to size. This would be a logical organization of knowledge. The order of things helps us to develop propositional knowledge represented in the form of concepts. Imagine a list of software programs that is ordered by application: game, graphics, spreadsheet, publishing, and text. But we want to move our students from organized facts to concepts and generalizations. From our animation programs grouped in the graphics category, we derive the concept of modeling. For our students we could describe what modeling involves, why and when modeling is important and the industries where modeling is most often used. Our generalizations take the form of inductive inferences. For instance, after observing the practices of the major automobile manufacturers in the U.S. over the past decade and the return to gas-guzzling engines, we can generalize that these manufacturers are more interested in protecting their market share than in clean air and energy conservation. We can say that procedural knowledge is technical knowledge and procedural plus propositional knowledge is sociotechnical knowledge.

Integrating Knowledge

We acquire procedural and propositional knowledge through observation, practice, reasoning, and reflection. We articulate knowledge through algorithms, concepts, directions, facts, generalizations, and strategies. We integrate knowledge into our experiences by constructing meaning and models, by shaping and organizing, and by internalizing and relating. Acquiring, articulating and integrating knowledge are active processes. When we confront a task that requires a procedure to complete, our mind attempts to construct a model of the task. When we confront facts our mind attempts to create meaning. We begin to integrate knowledge by constructing models and meanings. We reinforce the integration of models and meanings into our experiences by shaping directions into rules of thumb and organizing facts into groups and classes. One goal is to internalize knowledge and develop habits of procedural practice of design and technology. Another is to develop habits for routine access of the interrelationships among the facts and concepts of design and technological practice.

To develop knowledge of design and technology, students must actively integrate this knowledge into their experiences. They need time and opportunities to concentrate, practice and talk about what they are doing and required to do. Students need instruction in how to construct models and meaning, and shape and organize directions and facts in order to integrate what they learn into their experiences. These are design and technological practices that experts take for granted but novices find extremely difficult. It is not enough for teachers to merely provide directions and facts. There has to be movement in the realms of procedural and propositional knowledge.

Procedural Knowledge (Episodic Memory)

- **Constructing models:** We acquire procedural knowledge through directions and the eventual construction of models, rules of thumb, etc.
- **Shaping:** By re-shaping what we procedurally did into rules of thumb, we begin to integrate procedural knowledge into our routines.
- **Internalizing:** Ultimately, we want to internalize procedural knowledge by adopting and shaping new routines and strategies.

Propositional Knowledge (Semantic Memory)

- **Constructing meaning:** We acquire propositional knowledge through the construction of concepts, generalizations, and meaning derived from facts.
- **Organizing:** By organizing what we propositionally know, we begin to integrate propositional knowledge into our established concepts and discourses.
- **Relating:** Ultimately, we want to establish relationships and connections among facts and concepts by actively constructing meaning and reorganizing this into generalizations.

Organizing Knowledge for Instruction

Knowledge must be organized for instruction. This point is crucial for any form of education. Think about some of your most frustrating experiences in education. There is a good chance that your frustration was due to either emotional and physical discomfort or disorganization. And if the reason was disorganization, you probably experienced a disorganization of knowledge. Think about the running joke of technical directions that we receive when we purchase something that has to be assembled or installed, or when we purchase a new software application. Most of us discard the directions because we trust our own rules of thumb and strategies to trouble shoot and problem solve over the vendors' ability to organize knowledge.

In most cases with vendors, we witness a disorganization of procedural knowledge rendering the directions they provide useless.

Think about your own organizational skills. Do you consider yourself to be highly organized? If the answer is no, you will have to discard any pretense that it is ok to be disorganized. You need to commit to clear, concise organizations of knowledge for your students. It is not ok to be disorganized when it comes to knowledge and instruction. While our minds tolerate chaos and amazing amounts of disorganization, when it comes to knowledge our minds crave order, connections, and full stories. Order is often generated within chaotic systems, but confusion within an instructional system will more often generate anxiety.

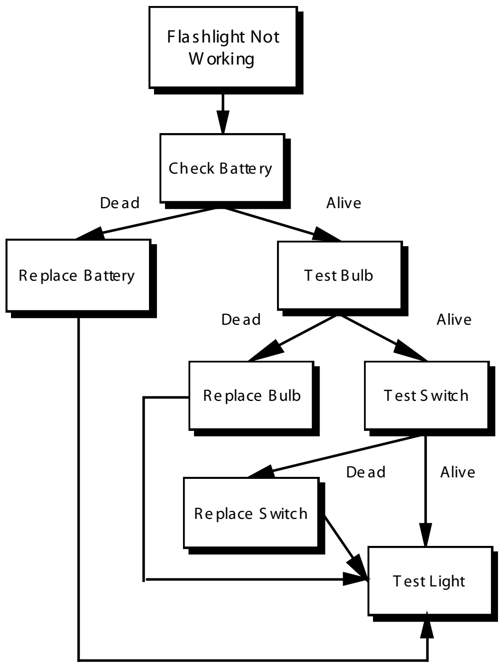
In the previous two sections, we addressed how we articulate and integrate procedural and propositional knowledge. To articulate procedural knowledge we have to organize it into directions, and algorithms and for propositional knowledge develop classification systems, concepts, and generalizations. There are several proven techniques for organizing procedural and propositional knowledge for instruction. Mind maps are very effective for organizing propositional knowledge but have shortcomings for organizing procedural knowledge. Information sheets are also effective for communicating propositional knowledge. Procedure sheets, on the other hand, work in tandem with demonstrations for the conveyance of procedural or technical knowledge. When you organize knowledge for your students you are actually preparing advance organizers. You are organizing knowledge in advance of your students' internal organization of the same knowledge. Advance organizers are absolutely crucial to the conduct of technology studies (Jones, Pierce, & Hunter, 1988).

Procedural Knowledge: Procedure Sheets

As we defined it earlier, procedural knowledge is basically know-how or how-to. Some people claim that know-how is the essence of design and technology without acknowledging that know-how by itself is inadequate to design, make, maintain, and regulate technological activities and things. We are not born with an innate procedural knowledge of how to safely play and work in the world. We develop procedural knowledge through education and observation. Once a teacher derives procedural knowledge through task analysis, the knowledge has to be organized.

Recall that procedural knowledge is defined by its procedural order: Step 1, Step 2, Step 3, etc. If the order is mixed, the procedure changes. With technical procedures that involve chemicals, heat or machines the displacement of one step with another could result in injury. Most mind maps and diagrams blur procedural order and allow for various interpretations of procedures. Of course, with procedural knowledge,

Figure 3. Flow chart of Flashlight Test System



various interpretations are not what we want. The only diagram that is effective for conveying procedural knowledge is the flow chart (Figure 3).

In technology studies, we typically demonstrate how individual procedures should be completed. We show the students how to safely and effectively complete social and technological procedures. As we realized in the first chapter, teachers dedicate a large amount of time to organizing the steps of a demonstration. We do this for two reasons: (1) to organize ourselves for communication and instruction, and (2) to organize the knowledge that we are sharing. Both propositional and procedural knowledge must be organized for and with the students.

Along with flow charts, the most common form for conveying procedural knowledge is the procedure sheet. Information and procedure sheets are complements. The organization of knowledge in the two formats is much different. Procedure sheets (and safety sheets) present directions in step-by-step format. They empower students with clear, concise directions for safely and successfully completing a technological procedure. Procedure sheets are invaluable in design and technology and challenge teachers to clarify instructions and reduce them to procedural directions. Procedure sheets, indeed procedures, need not be fully invented or contrived by teachers. Teachers should feel free to borrow and quote procedures from reliable sources. One major reason why teachers must be cautious with procedural knowledge is liability. When a teacher creates a procedure sheet, he or she is responsible for the information

Table 3. Procedure sheet

Procedure sheet

Table Saw: Ripping

Ripping is the act of cutting your work-piece with the grain of the wood--or "cutting to width"

1. Be ready to work safely!
2. Measure stock. If stock is 12 inches (30 cm) or longer you can use the table saw to rip. If stock is 4 inches (10 cm) or wider a Push Stick is not necessary. Otherwise, prepare to use a Push Stick
3. Check to make sure machine is off
4. Adjust the distance between your blade and the Rip Fence face to match the desired stock width. Be sure to measure this distance from a blade tooth that is "set" toward the Rip Fence.
5. Place the dimension of stock to be removed to left of blade
6. Adjust and lock fence in place and measure distance again. Readjust if necessary
7. Position and keep body to the left of blade until finished
8. Turn machine on--Concentrate on procedure, work-piece, and blade.
9. Begin your cut with one hand gripping your stock at the back edge in preparation for pushing it through the cut. If you're ripping short pieces of stock, position your other hand at the side of the stock (forward of the in-feed side of the blade) and pressing in on your stock to hold it firmly against the Fence. This "pressing-in" hand should not be near the rotating blade or pressing the stock against the blade after the cut has been made. If pressure is applied at a point where it closes the freshly cut saw kerf on the blade, a dangerous kickback will occur.
10. If you're ripping longer pieces of stock where you need both of your hands to safely hold and guide the stock forward through the cut (and the width of your board and the set-up permits), use a Featherboard (Stop: See teacher for this!)
11. When ripping narrow pieces of stock (10 cm or less) use a Push Block or Push Stick to move the stock through the cut once your "pushing" hand begins to approach the moving blade.
12. Carefully push stock through blade at even speed and once through let stock fall on floor or support table
13. Do not touch scrap to left of blade
14. Turn machine off
15. When blade stops spinning, lower it so that it is below the table surface
16. If you're ripping long pieces of stock, be sure you have plenty of work-piece support, both before and after you make your cut (Stop: See teacher for this)

within. If a procedure is flawed and a student is injured as a result, the teacher can be held liable. Consider a procedure for completing an operation on the table saw, and note the detail necessary to clearly convey procedural knowledge.

Consider an alternative procedure sheet for a table saw, where text is in a narrative format: "Start by adjusting the distance between your blade and the Rip Fence face to match the desired stock width. Be sure to measure this distance from a blade tooth that is "set" toward the Rip Fence face. Unplug your saw before taking this measurement. If your Rip Fence is properly aligned, you need only measure this distance at one point…" Which of the two would you feel most secure with? Why?

What are the advantages of the first format over the second? If the teacher fails to provide complete directions or inaccurate directions, and a student who follows these directions is injured, then the teacher can be held liable. Teachers can protect themselves by insuring that procedure sheets are accurate and derived from reliable sources (see liability, Chapter XI). Procedural knowledge ought to be organized in step-by-step format. See Chapter VII for a procedure sheet for a scanner.

Because you clearly demonstrate a procedure and develop a good, clear procedure sheet to supplement the lesson does not mean that students will automatically learn the procedure. As we will discuss in the next two chapters, students learn differently and have different preferences for learning. Some will retain a large portion of the procedure from the demonstration. Some will rely on the procedure sheet. Others will need to physically walk through the procedure and practice—they have to embody the procedure. Still others will rely on visual cues, such as color, to organize procedural knowledge. You may have to color code procedural steps: the initial steps green, the middle steps blue, and the final steps red. Recall that the movement through procedural knowledge ought to be from directions, to rules of thumb (algorithms) to strategies. Our goal is to not merely assist students in learning a particular procedure, but to assist the in developing rules of thumb and strategies for internalizing any procedural knowledge in the future. The goal is to help them to learn how to learn.

Propositional Knowledge: Images

Mind Maps

What is a mind map and why are they important? The reason why pictures are "worth a thousand words" is that they make use of a massive range of cortical skills: color, dimension, form, line, text, texture, visual rhythm, and especially the imagination. Images are therefore often more evocative than words, more precise and potent in triggering a wide range of associations, thereby enhancing creative thought and memory. In technology, the organization of knowledge is impossible without the benefit of images.

Mind maps, sometimes called concept maps or semantic organizers, are literally images of our ideas. Mind maps help us to convey large amounts of information in simple ways. Mind maps convey information of relationships in ways that other conveyances cannot. Mind maps are visual organizations of relationships (for example, paper clip, Chapter V). In 1969, a classic study demonstrated the importance of visual information as an aid to memory. Mind maps are much more effective than lists in triggering our memory and generating ideas. Key words or "basic ordering ideas" of mind maps act as triggers. Linear notes in the form of lists contradict the workings of the mind in that they generate an idea and then deliberately isolate it from the preceding and following ideas.

Mind maps harness the brain's tendency to function in gestalts or wholes and invite the addition of ideas to the key words on the mind map. They invite the brain to add in the beckoning areas. Once the mind is invited to associate anything with anything else, associations will almost instantaneously be found, especially when triggered by an additional stimulus. Mind maps are based on the logic of associations, not the logic of time (as in a list).

The basic ordering ideas (BOI) in any mind map are those words or images that are the simplest and most obvious ordering devices. They are the key concepts, gathering the greatest number of associations to themselves. A good way to find these BOIs is to ask (Buzan, 1997):

- What knowledge is required?
- What are my specific objectives?
- What are the most important seven categories in the area under consideration?
- What are the basic questions? Why? What? Where? Who? How? When? These are effective as major branches in a mind map.

Schematics

Mind maps are extremely important in technology studies. In fact, mind maps have more uses in technology studies than any other subject. However, the maps have their limits in communicating procedural knowledge. They are quite poor for this, unless in the form of a flow chart. Their primary value is in communicating propositional knowledge and symbols. Technology is often quite symbolic, and schematic. The language of technology is symbolic. Think of drafting and CAD. The use of abstract symbols conveys procedural knowledge. Symbols lend themselves to communication in technology because they are normally visual and a shortcut to conveying relationships or plans. Complex processes or systems can be easily described and depicted through symbols in a schematic. A schematic is a diagram that represents procedures, processes, and relationships. For example, the schematic below shows the complex concept of refrigeration and thermostatic control in simple terms (Figure 4).

Schematics reduce the technology to simple forms, so to speak. They make knowledge visible—they un-box black boxes. In electronics, designers work directly from schematic to circuit board to component. In the same way, students learn to

Figure 4. Schematic of Refrigeration System

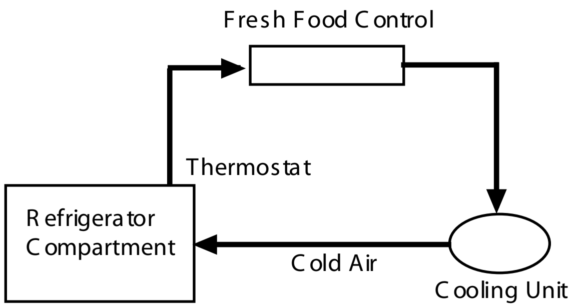


Figure 5. Diagram of Airfoil

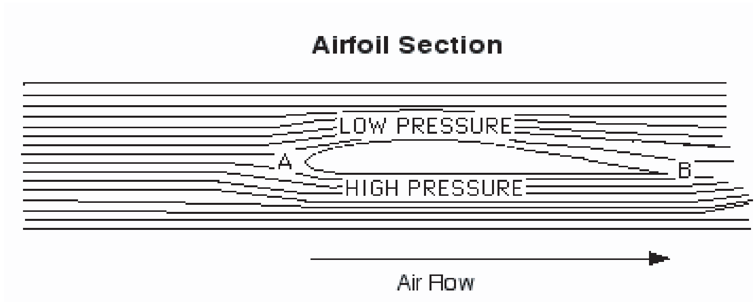
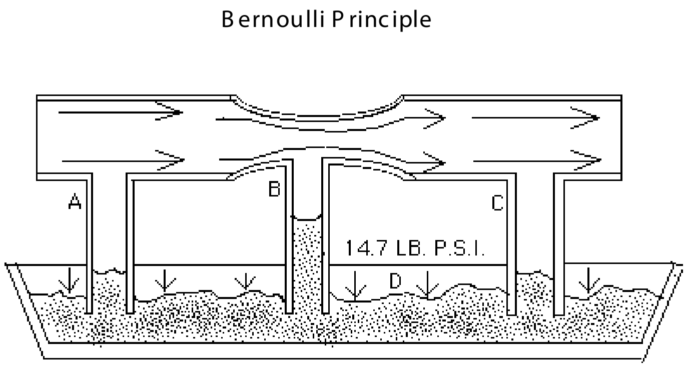


Figure 6. Diagram of Bernoulli Principle



breadboard from a schematic and build electronic circuit boards and components from the breadboard. Schematics and blueprints rely on symbols, many of which are universal for technologists. Electronic and interior designers learn a wide variety of symbols that they communicate with. When an experienced designer looks at a schematic, he or she typically knows exactly what components are required and where they go. Schematics provide a diagram of active systems as well as static systems (Figures 5 and 6). While a photo would be quite effective in its realism, it is not easy to find a clear photo of a cross section of the technology of interest.

Propositional knowledge of science that is central to technology is also effectively represented as a schematic (Figures 5 and 6). For example, an airfoil is extremely difficult to describe but can be easily represented in diagrammatic form. Why do the wings of an airplane create lift? What is lift?

The Bernoulli principle underwrites the design of airplane wings, and is readily demonstrated in a lab (Figure 6). To supplement the demonstration, a schematic of the principle would be extremely helpful. In the diagram, which depicts the Bernoulli experiment, we can see that the rate of air passing through the constriction of the tunnel increases, creating a low-pressure area. There is now a pressure differential, and the column of water in the middle rises in response to the drop in pressure. The water rises. The plane lifts.

The following schematic shows a conceptual model of a truss (Figure 7). The engineering forces and structures of the truss are clearly communicated in the diagram. The top and bottom beams carry main compression and tension forces. Diagonal elements transmit forces between beams. Forces change in these elements from tension to compression as the load traverses the bridge.

How can we represent our knowledge of levers and the principle of leverage that under girds many of our common hand tools? Are basic machines the basis of technology? Diagrams of the three classes of levers show the relationships among the fulcrum, or pivot point, the effort placed and the resistance incurred (Figure 8). The relationships define the class of lever.

Figure 7. Diagram of Truss

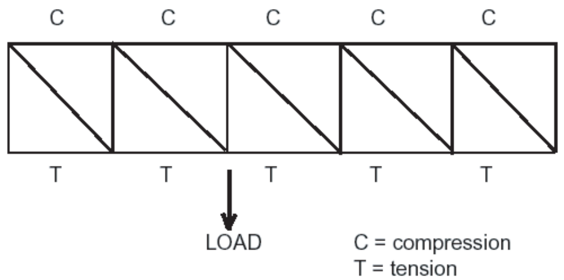
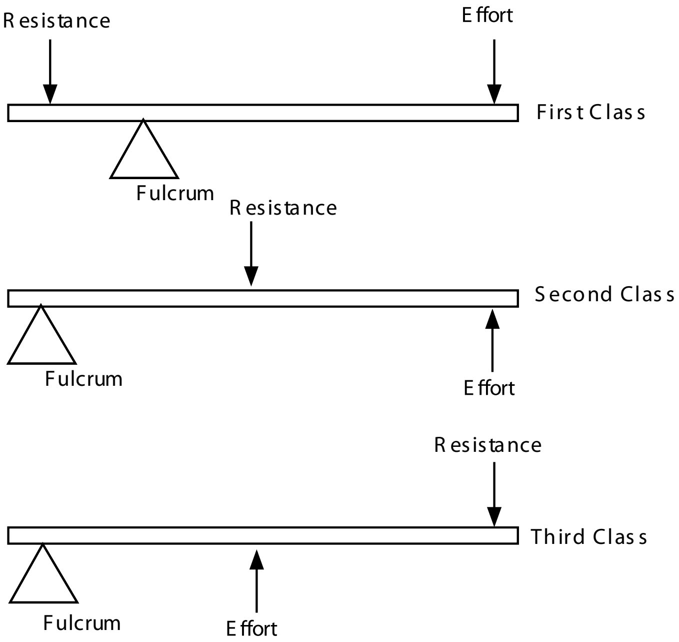


Figure 8. Diagram of classes of levers



Taxonomy Trees and Systems

Our reason for presenting the various schematics is to emphasize that the language of technology is symbolic and graphic. We can illustrate concepts and principles of technology so effectively because technology itself is actually illustrative of concepts and principles. Technology is the manifestation and representation of our ideas and knowledge.

Figure 9. Taxonomy tree of biotechnology discipline (Adapted from Wells, 1994, 1999)

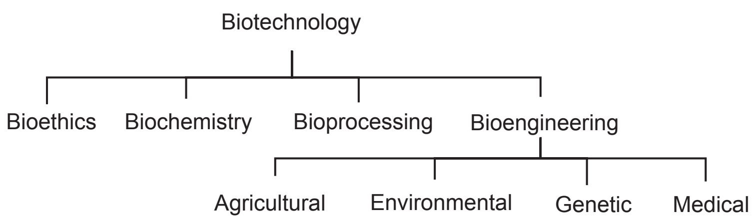
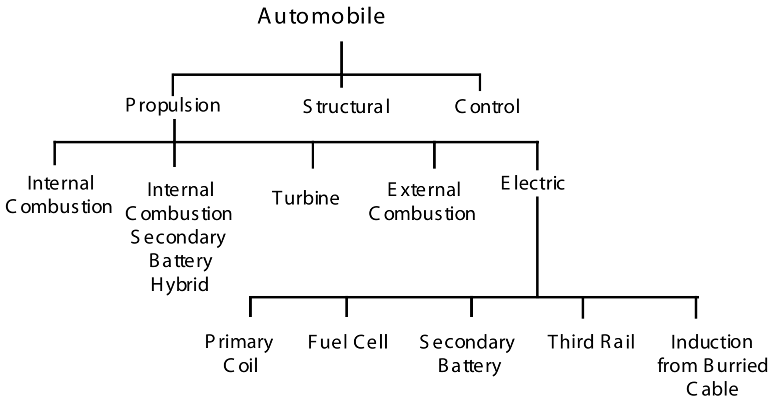


Figure 10. Taxonomy tree of automobile systems



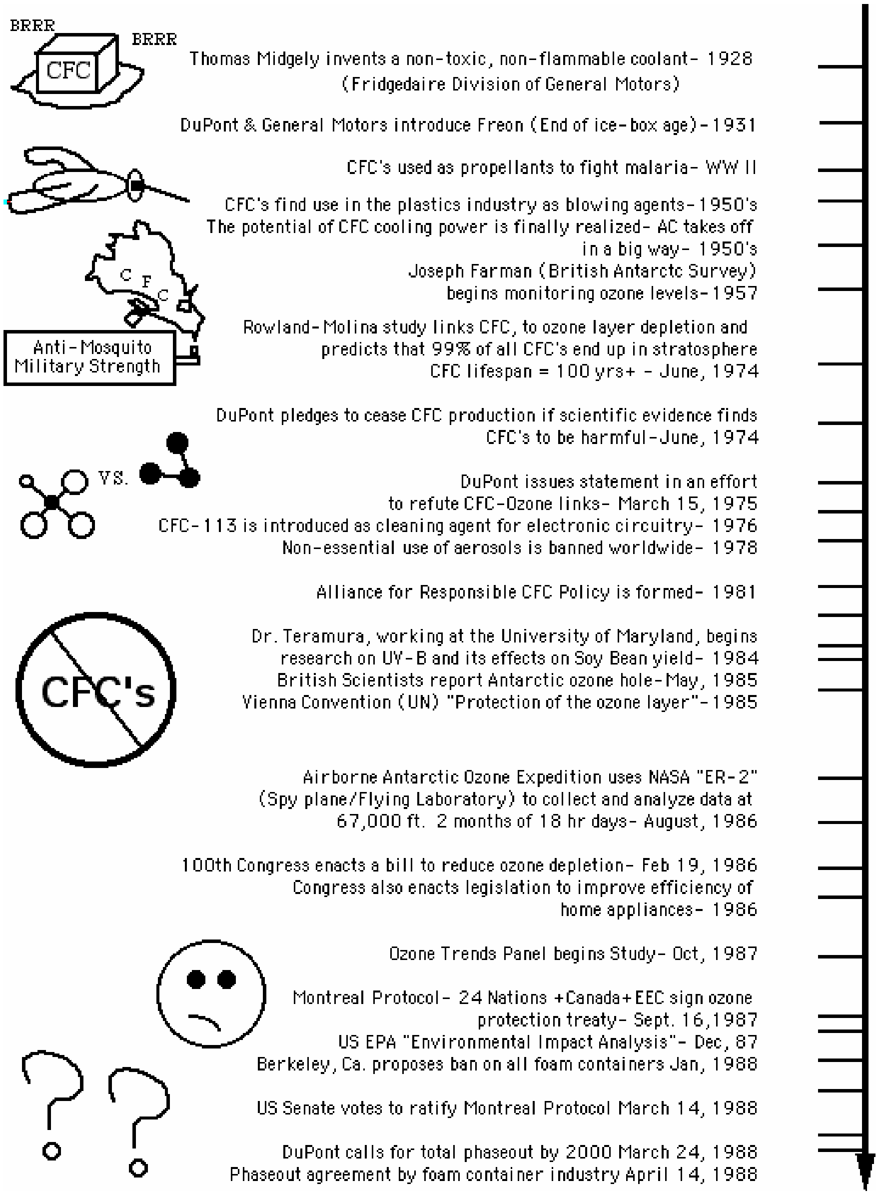
While the language of technology is graphic, our propositional knowledge of technology is often communicated through words and numbers. The next two figures are simple taxonomy trees or systems diagrams. The first represents a biotechnology subdivision or system of technology. The taxonomy tree, family tree, or systems diagram effectively represents one way of analyzing and classifying technological knowledge (Figure 9). Taxonomy trees are useful for mapping the conceptual aspects of technology. In Chapter I, we mentioned the value of thinking systemically and systematically about instruction. Taxonomy trees help us to think in terms of systems. The caution, however, is that as we map some essences or key components of a system, we risk ignoring others.

The taxonomy below effectively depicts an automotive system, or specifically the options in an electric propulsion system for an automobile. Like other maps, taxonomies communicate order and relationships. Tree formats are hierarchical arrangements or classifications of concepts (Figure 10). Systems can be divided and subdivided into any number of components. Like mind maps and schematics, taxonomy trees are advance organizers for students. They effectively organize and simplify knowledge. When we organize data or information we create knowledge. While essential to teachers, it is extremely important that students develop and utilize these mapping techniques as well.

Timelines, Tables, Charts, and Graphs

While images are extremely effective, propositional knowledge is also quite effective in timeline, table, chart, or graph form. Timelines organize knowledge chronologically by serializing dates, names, places, and events (Figure 11). Timelines are a key to organizing historical knowledge for your students. At one time or another,

Figure 11. Timeline of CFC Events



nearly every technology that teachers teach will have to be placed in a historical context. Timelines are also quite accessible to students, who can create their own sequences of events related to one technology or another.

Table 1. Table of Production of CFCs

Fully Halogenated Alkanes
U.S. Economic scope (Annual)

APPLICATION	INTERACTION WITH SIOCIETY	VALUE OF PRODUCTS /SERVICES	DIRECT CFC RELATED IND. EMPLOYMENT
REFRIGERATION	85 million hsehld 'Fridges 28 million hsehld freezers 178,000 Fridge Trucks 27,000 Rail Cars 160,000 Food Stores 39,000 Supermarkets 250,000 Restaurants	$6 BILLION	52,000
AIR-CONDITIONING	40 Million homes/ess all offices, com., public bldgs	$10.9 BILLION	125,000
MOBILE A-C	60-70 Million autos & trucks	$2 Billion	25,000
A-C & REFRIG SERVICING	All existing Fridges & A-C's	$5.5Billion	472,000
PLASTIC FOAM	Insul Foam for homes, fridges. food trays/pack. cushion foams	$2 Billion	40,000
SOLVENTS	Microelec circuitry, Spacecraft and computers	Billions	?
FOOD FREEZANTS	Frozen Fish, shrimp, fruit & vegies	$0.4 Billion	<1000
STERILANTS	Medical items, catheters, respir units, supplies, drugs	$0.1 Billion Steril. Equip.	<1000
FIRE PROTECTION	Extinguishers	Millions	?
	TOTAL (ex. solvents, fire ext.)	$26.9 Billion	375,000

Take the issue of CFCs and the depletion of the ozone layer of the Earth. We rarely hear about this issue anymore, but the ozone “hole” keeps growing larger, and cases of skin cancer across the world continue to increase. The links between the two may not be as causal as some claim, but the reality of a more dangerous sun is undeniable for those living in the southern hemisphere. How do we teach about this in a technology course? How can we organize what we know about the facts? We can begin by looking historically at the issue. Willis Carrier developed an air-conditioning system in 1902. But his system was dependent on cold air drawn from ice and cold water. It was not until twenty-five years later that Thomas Midgely invented a coolant and DuPont and General Motors eventually introduced Freon. By the mid

1980s, when the ozone hole was recognized, the US was producing more than their share of CFC's in the form of 2.7 million new residential air conditioners, 5.8 million refrigerators, and 1.1 million freezers per year. Rolling off the assembly lines were 7.8 million cars and 3.4 million trucks and buses. But all of this is better organized in graphic forms (Figure 11, Table 1).

Tables organize a range of data that can be cultural (number of hours of television viewed in one year), social (number of females employed in high tech industries) or technical (measurements in a wind tunnel). The visual representation of data with tables, charts, and graphs is extremely helpful to communicate propositional knowledge in technology. Scientific visualization is the concept that refers to the development of techniques to present scientific and technical information. With the power of digital graphics, the graphic presentation of information is limited only to our imagination. During the 1990s, there was a revolution in capabilities to animate and present information in three-dimensional models. Modeling has completely transformed capabilities for organizing and representing technical information for architects, astronomers, designers, geologists and geographers, for example.

Charts and graphs are essential for demonstrating ratios and relationships ranges of data. At a glance, they help us to draw inferences. They help us to establish facts from data and generalizations from facts. Pie charts provide visual portrayals of percentages or ratios. The two pie charts below indicate the changes in labor force distributions in the U.S. at two different points in history (Figures 12a, 12b). The increase in the manufacturing sector was reflected in the marketing and popularity of home conveniences, such as air conditioners produced by Carrier and York.

Figure 12. Pie Charts of the US Labor Force, 1920, 1984

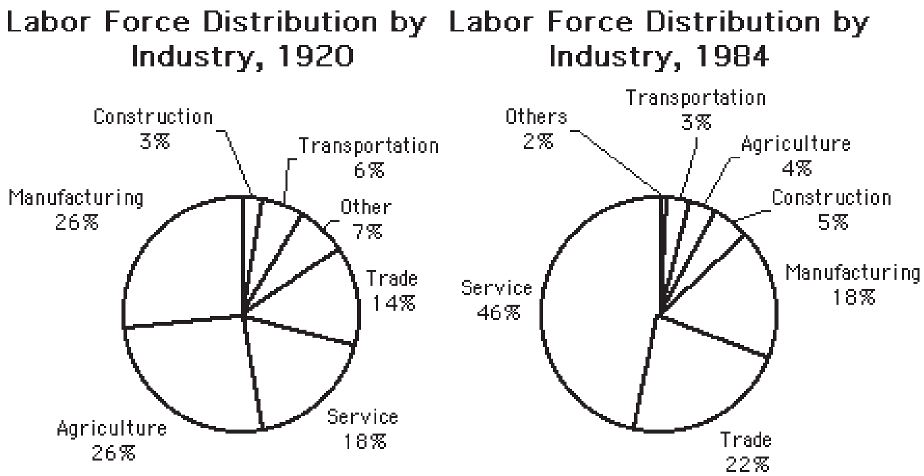


Figure 13. Bar Graph of US Passenger Carriers, 1939-1978

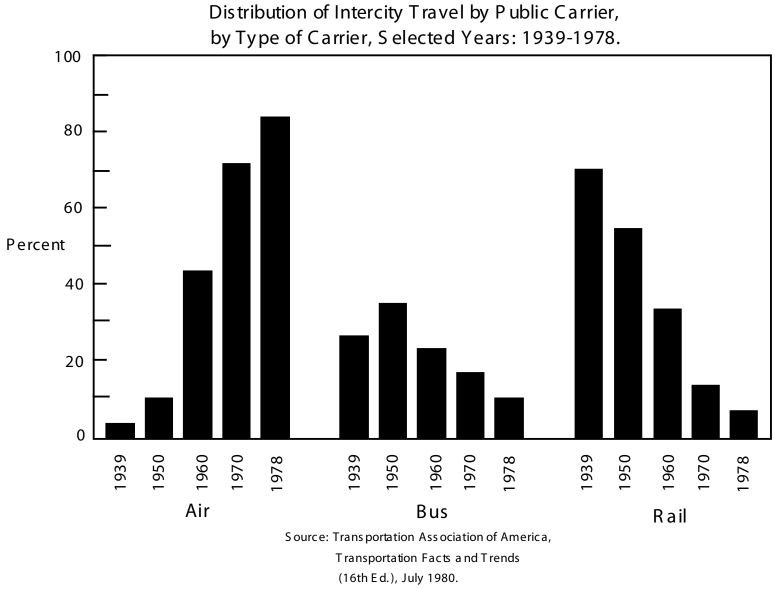
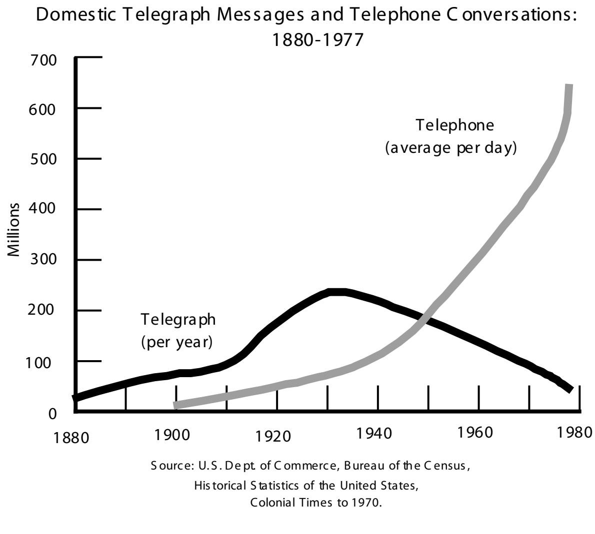


Figure 14. Line Graph of Communication Messages, 1880-1980



There are generally two types of graphs: Bar and Line. Somewhat like pie charts, bar graphs allow us to compare discontinuous categories of data. For example, the bar graph below allows us to compare passenger carriers in the U.S. at five different points in time (Figure 13). Line graphs allow us to compare continuous data over time (Figure 14). They are extremely effective for plotting changes over time. Graphs help provide a visual record of technological data. For example, at one glance we could infer from plotted measurements in a wind tunnel at different speeds, the volume of spam received over a month or the rise and fall of telephone and telegraph messages over a century (Figure 14). For some reason, students learn to associate graphs with math and science and fail to associate graphing with design and technology.

Technology teachers should feel comfortable using a variety of techniques for organizing propositional knowledge. There are varieties of mind map styles for organizing propositional knowledge and for communicating. Hub designs, fishbone designs, network designs, trees, and webs employ different ways of relating concepts. Mind maps and schematics are effective for conveying propositional knowledge but quite ineffective for dealing with procedural knowledge. Practice communicating with schematics that are sketched, drafted, or scanned. Make liberal use of diagrams, timelines, tables, charts, and graphs to communicate with your students. Venture into the world of scientific and technical visualization to animate knowledge and make it clear and visible. The images that you create with these techniques will serve as advance organizers for your students (Jones, Pierce, & Hunter, 1988).

Scientific and Technical Visualization

Scientific and technical visualization (Sci Vis) is a field that became extremely popular during the 1980s and 1990s due to the availability of powerful hardware systems and accessible imaging software. Books published by Tufte, such as The Visual Display of Quantitative Information and Envisioning Information laid the theoretical foundation for this popularity. Digital animation and simulations transformed the way that scientific and technical information could be displayed or presented. Modeling software, such as AutoCAD, Pro-Engineer, Pro-Desktop, and TrueSpace provided powerful tools for manipulating vast amounts of data for design and analysis. Animation software such as 3D Studio offered complex techniques for giving motion to static data and for simulating live action. Scientific and technical visualization were transformed. One of the most effective visualization databases was McCauley's The Way Things Work, which demonstrated how the new techniques could be used to animate the workings of a wide range of technologies. Teachers who once struggled to demonstrate the internal workings of combustion or electrical power generation turned toward the new techniques of Sci Vis to clarify what they were teaching. Technology teachers finally had the tools and techniques to represent the 3D world that they once struggled to represent in 2D. In the late 1990s, Sci Vis became a course option in the digital media design curriculum (Clark

& Wiebe, 2001; Wiebe, 1992; Wiebe & Clark, 1998). It is essential that technology teachers have the skills to draw on these new techniques for organizing knowledge and for assisting students to animate, model and simulate. Scientific and technical visualization reduce visual forms to four primary attributes:

- Form (metric or stereometric form; shape of line, surface, 3D solid).
- Surface characteristics (color, pattern, texture, thickness).
- Spatial relationships (relationships of forms and surfaces in space).
- Temporal qualities (movement via frames and vectors; static and dynamic qualities).

Sci Vis requires that we understand how to represent and manipulate these four attributes via hand rendered drawing and photography or computer software. Representation of the world of science and technology is basically either concept or data driven (Jones, Pierce, & Hunter, 1988). Concept driven representation deals with scientific or technical concepts such as internal combustion, nanotechnological movement, or hydraulic flow. Data-driven representation deals with data such as pollutants and particulates in urban centers or PCB build-up in small lakes. Eric Wiebe, pioneer in introducing Sci Vis to technology studies, has inspired teachers to create learning objects and databases or images for teaching biotechnology, medical imaging, molecular modeling, and robotics, among other fields.

Propositional Knowledge: Information Sheets

Typically, mind maps, schematics, charts, graphs, and timelines appear within information sheets, which are used as handouts. Information sheets provide the who, what, when, and why, or background and context for design and technological practices. They reinforce the procedural with propositional knowledge and are essential to developing technological literacy in students. Generally, each procedure sheet ought to be accompanied by an information sheet. Information sheets may provide a geographic or historical background, may describe the mathematical and scientific principles underlying a technology, or may present ecological issues related to a practice. They may expand on the technological concept at hand or provide a description of the operations of an application, tool, or machine. There is a wide range of possibilities for information sheets. The information sheet below is presented as a technological literacy dispatch.

Technological Literacy Dispatch

Levi Strauss & Co. Closes Last Two U.S. factories—Canadian Factories will Close in March

After celebrating its 150th year anniversary on 5 May 2003, Levi Strauss & Co. closed its last US factory in San Antonio, Texas on Friday, January 9th. This closing is symbolic of the trend of textile manufacturing and other industries, which shifted operations into Asian and Central American sweatshops to take advantage of (i.e., exploit) foreign labor (mostly women) who work for $1 per hour. Levi Strauss was paying US workers $11.00 to $14.00 per hour. The last three Canadian factories, in Brantford, Edmonton, and Stoney Creek, closed in March 2004.

Figure 15. Line graph of Levi Strauss factories

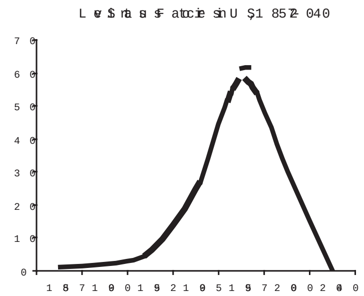
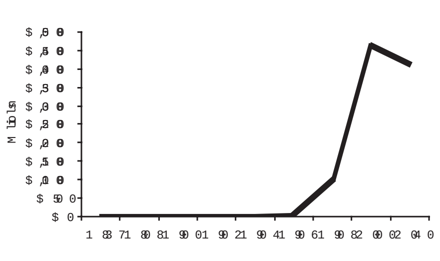


Figure 16. Line graph of Levi Strauss factories



At that time, the final 1,180 Levi Strauss and Co. factory jobs in Canada were eliminated. Levi Strauss & Co. total sales "stagnated" in 2002 at $4.1 billion after a peak of $7.1 billion in 1996. A Levi Strauss spokesman, Jeff Beckman, promised "we're still an American brand, but we're also a brand and a company whose products have been adopted by consumers around the world." "We have to operate as a global company."

The propositional knowledge of an information sheet must be accurate and factual. This requires that a fair amount of research and synthesis be completed prior to the creation of an information sheet. Certainly, the information and images provided can be paraphrased and scanned from sources. In most cases, the information retrieved has to be condensed or rewritten to be appropriate for the audience of students. Most technology teachers would create an information sheet to complement the micrometer lesson plan provided in the first chapter. It would be used as a handout and as a guide for the teacher in a demonstration that deals with various issues related to the micrometer. Given what we know about graphic design, what would an effective information sheet look like? What determines the quality of an information sheet? The key is to develop a format that you can consistently use and is consistent and responds to principles of graphic design. Information sheets deal with propositional knowledge and procedure sheets with procedural knowledge (see Table 4).

Table 4. Handouts for technology teaching

Definitions: Handouts for technology teaching
Activity sheet: This handout explains the reason and procedures necessary to complete an activity that is not a design challenge or project.
Design or project brief: This handout provides the information necessary, such as problem, constraints, and assessment criteria, for completing a design challenge or project (Chapter V).
Exercise sheet: This handout presents provisions for development of knowledge and skill regarding academic or technical content.
Information sheet: This handout provides knowledge (who, what, when, why) regarding the background or context--ethical-personal, ecological-natural, existential-spiritual, socio-political--of some application, apparatus, material, peripheral, tool, machine, or process. (Propositional knowledge)
Procedure sheet: This handout explains, in detail, the knowledge (how) and technique necessary to use an application, apparatus, material, peripheral, tool, machine, or process. (Procedural Knowledge)
Safety sheet: This handout provides necessary knowledge regarding safe practices in laboratories workshops, and in use of apparatus, materials, peripherals, tools, machines, and processes.

Projection and Reflective Practice

We began this chapter by reviewing the new views of intelligence and their relation to knowledge. We defined procedural and propositional knowledge and explained how knowledge is articulated and integrated into experience. We also drew distinctions between technical and sociotechnical knowledge. A range of effective techniques for organizing knowledge for instruction was presented. These techniques serve as advance organizers for students. Mind maps, schematics, taxonomies, timelines, graphs, charts, information sheets, flow charts, and procedure sheets are invaluable techniques for creating advance organizers. The field of scientific and technical visualization has transformed the way that technology teachers organize knowledge and present ecological, social, and technical processes. We described a range of cognitive skills that are employed in design and technological processes. In the next chapter, we address action and emotion and their interrelations with cognition.

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Chapter III

Feelings, Values, Ethics and Skills

Introduction

We began this book by acknowledging that the mere word "technology" provokes strong emotions or feelings from the heart. Advertisers play on these emotions by using technology and language to incite interest and action. For some people, design, skills, tools, and machines produce fear and feelings of insecurity. Others feel power and security. Some feel excitement and some dread and stress. Very few of us are unmoved by technology. While skills and technology generate strong reactions within us, we are *not* passively moved; technology does not merely act on us. We actively participate; we actively control, manipulate, resist, or negotiate technology. We bring our attitudes, fears, hopes, and values to bear on our skills and technologies. Our values are always present in our actions. We assert some and suppress other values when we act. We may value what technology can do for us or what we can do with our technologies. We may value what technology cannot do for us. The purpose of this chapter is to contradict the distinctions that we commonly draw among emotions, skills, and technologies. On one hand, technology provokes strong emotions and visceral responses. On the other hand, many technologists are committed to removing emotion, the most misunderstood of "human factors," from their work and technology.

As teachers, we are challenged to recognize the feelings and values that our students bring to technology studies and particular technologies. Our task is to validate, direct, and transform the emotion in our students' experiences. Ultimately, we want our students to feel empowered by skills. However, this does *not* mean that we or our students need to feel good or positive about all technologies or technology. Neither our students nor we need to celebrate or denigrate all technologies. Nor can we feign neutrality or encourage neutrality. Perhaps the last thing we want to do is inspire nihilism, or the feeling that life and values are pointless in a technological world. This can easily be the result, when we often insist that technology is accelerating and determining our destiny. We need to work with our students to pick and choose those types of technologies that they and we ought to favor and those that we ought to disregard. We ought to be able to work with hope and despair. This chapter provides a language and various techniques for making these choices. If in the previous chapter, we dealt with issues of the head, in this chapter we deal with the heart, hand, and feet. If we dealt with cognitive pluralism, we will now deal with emotional and kinesthetic pluralism.

Technology and Emotions

Except for the technologies of advertising (images, sounds, etc.), most people argue that technology is devoid of feelings, emotions and values. Technology for most people is cold and incapable of the types of intimacy found in everyday human life. Some people tend to feel that technology is neutral and any emotions associated with particular technologies are dependent on the way they are used. Others feel that technology is inherently good or inherently bad, and trust or distrust particular technologies. Some of these people concede that certain technologies have emotions, such as anger or pleasure that are embedded in the technology itself. They acknowledge that some technologies are quite durable and impervious to uses other than which they are designed. The technologies retain the imprint of the early intentions of their designers. The initial fixing of technologies is a powerful determinant of their uses over time, similar to the initial defining of concepts and phrases. Other people who concede that technology has emotions or values admit that some technologies are quite pliable. These people suggest that technologies readily respond to various uses. So we arrive at a crucial question. Is it technologies or people that emote? Or is it both? We can also ask: If technology is so cold and devoid of emotion and values, then how can it generate such strong feelings and visceral responses?

"Watch yourself," my father would say, "that's a mean drill." It was a serious Milwaukee reciprocating drill and had caution and danger written all over it. My father warned me, nearly every time I used it, that the drill could break bones or crack teeth if I was not careful with it. Cased in an aluminum and steel housing, painted red and silver, two handles, the drill *looked* aggressive. I approached it each time with a certain amount of trepidation and fear. "If you're scared of it," my father warned me, "it'll break your nose." So I had to feel nervous and confident at the same time. Gender was a big part of this ordeal. I had to act confident; I had to look confident. I had to behave as if I had it all under control and I had to boast or joke about my confidence. "Yea, right dad, the Milwaukee doesn't know who it's dealing with. This thing would chew up a wimp and spit him out!" If anyone was watching, I would grab the drill with authority and mimic all of the jackhammer guys in pictures that I had seen. Underneath it all, I was still scared of this thing. If the drill bound and twisted, my dad would give me an "I told you so" look. It confirmed our fears and respect. It was truly a mean drill.

Was the Milwaukee drill really an inanimate object with no emotional qualities to speak of? Did my father and I merely project our fears onto the drill? Was the drill then invested with all sorts of emotional qualities, much like a stove, that dictate our careful behaviors? Does the emotional quality—the meanness—of the drill depend on how it is used? Or did the drill really possess aggressive qualities—wicked torque, power, and speed—that one had to confront each time it was used? When I used the drill, were its qualities confirmed? Was the drill's reputation as a mean machine confirmed and was I merely a medium for the drill to express how mean it was? And what about me, full of emotion and volition (i.e., will), when I used the drill? Was I transformed from a sixteen-year-old boy into an aggressive, jackhammer-drilling man when I held the drill in my hands? The drill was no longer merely a drill and I was no longer merely a boy. We were transformed into a hammer-drilling unit.

The key to understanding the interrelations between technology and emotions is to avoid falling into the trap of original essences (Latour, 2000). Neither technologies nor people are immutable and neither has eternal qualities. Technologies change when they are used and people change when using technologies. One lesson is that technology and feelings cannot be separated. Technology in action necessarily generates emotions. A driver in a car may feel mobile and independent or trapped and dependent. Theorists argue that the spectrum of feelings for technology extends from technophilia (love of technology) to technomania (obsession with technology) to technophobia (fear of technology), or from technocracy (basic trust in technology) to luddism (basic mistrust of technology). They note that relationships with technology are rarely either love or hate, but most often fall somewhere in between. The more scientific theorists dismiss feelings that tend to extremes as irrational and overly subjective. Rational feelings are moderate, or moderated by objective facts about the nature of technology and human nature. Is it possible to stay cool and objective or do we uncontrollably have feelings, one way or another, toward technology? As teachers, can we merely advise children and teenagers to stay cool, or do we have to take their feelings into account?

Do robotic pets have feelings and can they express these feelings? If these feelings are merely simulated, then what is the difference between the real and synthetic if we respond the same way? In the movie *Toy Story*, the toys were animated by the child's imagination. The older toys basically depended on the child's imagination for their action and response. However, with arrival of the robotic toys, their dependence on imagination is not so clear. Tamagotchis neither look anthropomorphic nor like a pet, but they provide an emotional response to emotional attention. One could argue that the Tamagotchi was nothing more than a plastic shell that enclosed an electronic circuit of a microprocessor that was programmed to mimic some rudimentary emotions. Any feeling that the Tamagotchi felt was projected onto it by its owner. One could argue that we are attributing a human quality to an electronic object. One could accuse us of a crude form of animism. These charges would nevertheless overlook the fact that computer technologists actively design and construct emotional machines.

The new pets are given their emotions through a system of micro-sensors and emotionware. When the Furby pet was released in 1999, children immediately identified with its emotional qualities. It could laugh and cry, and express a range of feelings through over 300 different ear, eye, and mouth movements. Sony's Aibo, a robotic dog, expresses six distinct emotional states. Aibo expresses joy when it receives praise, sadness when neglected, and anger if provoked. Aibo expresses fear of falling, is surprised by sudden movements, and discontent if teased. Do the pets merely recognize and respond to emotions or are they capable of having emotions?

This issue, whether machines can have emotions, is central to what Rose Picard (1997) calls "affective computing." Affective computing is basically an expansion of computer scientists' interests from artificial intelligence (AI) to Artificial emotional intelligence (AEI). Since the 1960s, AI dominated the interests of programmers and found expression in everything from industrial robots to game playing computers such as Deep Blue. It is clear that computers can think and reason, and demonstrate high levels of logic in complex affairs. During the same decades however, it also became clear that cognition requires emotion. The highly rational thought of *Star Trek's* Mr. Spock, somewhat limited to science fiction, is ineffective for making important, value-based decisions. A balance of emotion is necessary for intelligent decision making—not too much emotion and not too little emotion. Computers with AI have tended to perform extremely well when encoded with a huge set of decision rules (i.e., if this, then this) but have performed poorly in making important decisions or judgments. Hence, the current trend expands AI to include AEI—toward "machine ontology" and cognitive and emotional pluralism.

Affective computing embraces three realms of emotional intelligence. An emotionally intelligent person is skilled in understanding and expressing her or his own emotions, recognizing and responding to emotions in others, in regulating affect, and in using moods and emotions to motivate responsive or sensitive behavior. EI means that one recognizes feelings as they are occurring and is aware of how to best express emotions. This requires that one appraises the feelings of others, empathizes, and responds to communicate that emotions are understood. EI means that one regulates feelings, such as reducing anger or anxiety to understand the causes. This means regulating one's own feelings at times to enable and demonstrate respect for others. Emotionally intelligent individuals also utilize feelings to accomplish goals. They take advantage of emotions to motivate themselves and plan, often delaying gratification. They also help others to use their feelings in the service of their goals. In two words, emotionally intelligent individuals are *highly sensitive*.

Can computers—machines—emote in intelligent ways? Should we hope for empathy from a computer? Since machines and humans are physiologically different, we cannot expect emotional experiences and expressions to be identical. The emotional health of humans and machines will differ accordingly. Computers empowered with levels of emotional intelligence may suffer from emotional disorders that are quite different than the disorders in humans. At this point, affective computing simply means that computers are being and will be designed to interact on emotional levels. This does not necessarily mean desktop computers. Rather, wearable computers and robots will be the primary technologies for emotional interaction.

We can generalize that media, tools, and machines, somewhat like advertisements, are basically designed to control our emotions. The discipline most directly involved in designing technologies that respond to people, and people that respond to technologies, is ergonomics or human factors. Ergonomics is concerned with an *interface* between human (social) and non-human (technological) *systems*. But design is not merely about interfaces between humans and technologies. Design, especially architectural and interior design, is about controlling total environments, systems, and experiences. Design is about controlling emotions. In Chapter VI, we describe the interrelations among doing, knowing and feeling in technology studies. In Chapter XI, we describe how technology labs and workshops control your students' emotions.

Our emotions are triggered daily by the technologies that surround us and with which we interact. During the early 1900s, when Henry Ford innovated with assembly line technologies in his Detroit factories, the stresses of work were made explicit. Assembly line innovations were accompanied by the new psychologists whose interests were in monitoring the thresholds of human endurance in technology intensive work. Today, the technologies that induce emotional stress are legion. Many children, teens, and adults are struggling with emotional sensitivities heightened by the new technologies and irritated by the resultant increased pace of life. Lights, sounds, and information are primary stressors for many people who often feel apprehensive, nervous, or jittery in certain environments or when working with certain technologies. Of course, a technical fix for some emotional stresses is mood altering devices (e.g., light box, synthetic musak, ionized air, air conditioning, designer scents) and drugs.

Technostress is a real phenomenon these days for most us, and not merely for factory and office workers. Technostress is "any negative impact on attitudes, thoughts, behaviors, or body physiology that is caused either directly or indirectly by technology" (Weil & Rosen, 1998, p. 5). Even the most technologically literate among us feel frustrated, overwhelmed or even downright stupid at times in the face of particular technologies. Confronted by new technologies and a collective mass of technology in general, we often feel alienated, anxious, embarrassed, dependent, or inadequate. Technostress is emotional and takes its toll on the body. It is not just reactive stress that is embodied. Technology itself is embodied, as a fair amount of stress is due to identity attachment. More than ever, people's egos, identities, and pride are completely enmeshed with and dependent on technology.

Some theorists facetiously note that there is an innate spitefulness to inanimate objects. Technologies, they note, work against us to irritate and resist control. In the 1960s, this philosophy that "things are against us" was dubbed resistentialism. This philosophy is built around the most basic theorem of Murphy's Law stating that "if there is a probability that things *can* go wrong, then they *will* go wrong." Since the dawn of the bug-ridden, glitch-filled computer age, many have rallied to resurrect resistentialism as a philosophy of things. Even the most confident among us has begged our computers to please give us back the only draft of our file. All of us have experienced "the what you see on your screen is not what you get from the printer." We want to pull our hair out or the computer's wires out when, in designing Web pages, links work on the local desk top system bust not on the remote server. Same file in two places, but two different responses by the computers. Recalcitrant things resist us. Wear a white shirt and watch things drop on it to soil it before we get out the door of our home. When things don't work, we get emotional; some of us get extremely anxious and frustrated or angry. Sometimes the only choice is to either manage our emotions or smash the resistant machines.

If we ascribe feelings to objects, digital or otherwise, are we crossing the line into animism or anthropomorphism? More specifically, are we technoanimists? Perhaps, but nothing dismisses us from attending to the feelings that our students have for technologies and skills. As we noted in the introduction of this chapter, design and technology provoke emotions and this is the reality. There are very good reasons for teachers to attend to their own and their students' feelings towards technology and skills. Some argue that if we attribute feelings to technologies or natural things, we will develop respect for the built and natural worlds. Others argue that by tuning into the emotions of design and technology, we will develop an empathy for and cognizance of emotional labor.

Emotional Labor

Emotional labor, a concept coined by Arlie Hochschild, has two very different definitions. First, this concept refers to the effort, planning, and control necessary to express the emotions that organizations demand during interpersonal transactions.

Most businesses exert a certain amount of emotional control over employees, such as check out clerks, who are required to put a happy face forward in interpersonal transactions. Emotional labor involves the effort to emote more or less on cue. This labor requires an internal response and external display of emotions. Emotional labor also involves the demands made on employees or students in terms of expectations and intensity of expression. Real emotions are invariably masked by emotional labor, and the difference between raw feelings and shaped feelings creates emotional dissonance, and this itself is a stressor.

Situations require that emotions be managed. For example, a date or a card game has certain rules that govern the management of emotions. Emotional labor refers to the work done in managing feelings according to rules of the situations. Erving Goffman (1959), the influential social researcher, called this "impression management." Regardless of the outcome, there is a fair amount of work that must be done to manage emotions that are more or less controlled by the conventions and rules of the situation. These can be quite formal, as in the rules of etiquette at a dinner party, classroom discussion or a golf game. Or the rules can be informal, as in the rules of interaction governing a conversation or the purchase of groceries. Emotional labor in these situations requires that outward impressions and inner feelings be actively managed.

As described in the previous section, even the simplest technologies influence or govern the way we manage our emotions. Technologies, whether drills or computers, stimulate emotions that are generally beyond our control. We feel excitement, fear, or reverence. We have to actively work to evoke or suppress certain feelings to carefully, safely, or successfully use many technologies. The same technologies that stimulate our emotions also prompt us to assess and manage how we feel before we use, and while we are using, these technologies. The new surveillant technologies, from keystroke and e-mail monitoring software to public cameras, prompt us to control our behavior as well as our emotions. In order to safely use electrical and power tools and machines, we have to manage our emotions. Overzealous feelings or extreme fear are, in most cases, inappropriate for the use of tools and machines.

The second definition of emotional labor refers to the everyday emotional work that is done and goes unnoticed. Feminists point out that, typically, women are responsible for the bulk of emotional labor in families, relationships, and organizations. Yet, this labor generally goes unrecognized or is without reward. This extends from the emotional labor necessary for care giving to the emotional labor necessary for the maintenance of relationships. Those who are skilled in emotional labor, or who have high levels of emotional intelligence, and enter the waged labor market usually end up in the low status jobs and professions. Nursing, social work, and teaching tend to be relatively low status and cluster at the low end of the professional pay scale. Emotional labor is high skilled but low status.

Teachers must recognize that emotional labor is learned, required for conformity in certain organizations and situations, and is undervalued as the work of many females and males. Technology teachers must also recognize the role of emotional labor in their own work and the work of their students in the labs and workshops. Students are going to approach media, tools, and machines with strong feelings: ambition, anger, anxiety, confidence, envy, excitement, fear, jealousy, intimidation, power, risk, resentment, or satisfaction. The development of skills is charged with all sorts of feelings. Technology teachers have to teach students how to manage their emotions or how to do the emotional labor necessary for practice with media, tools and machines. The intent of technology studies is *not* to overcome all expressions of technophobia. Rather, the intent is to work with students and their emotions to provide new opportunities for expression and to expand potential. Rather than a leveling of feelings, the intent is to assist boys and girls in expressing and tuning into feelings.

Emotional Intelligence

Emotional intelligence (EI) is typically closely associated with emotional labor. There are great differences in the quality of emotional labor among individuals. Some individuals are quite adept at managing and regulating emotions for effect, while others are generally incapable of expressing themselves through emotions. These individuals possess different levels of emotional intelligence. Theorists Salovey and Mayer (1989), define EI as "the ability to monitor one's own and others' feelings and emotions, to discriminate among them and to use this information to guide one's thinking and actions" (p. 189). EI is very closely related to Gardener's personal intelligences, as we noted in the previous chapter. EI, like the interpersonal and intra-personal intelligences, refers to the recognition of emotional states, in oneself and others, to solve problems and guide actions.

Basically, there are three areas of EI: Appraisal and expression of emotion, regulation of emotion, and the utilization of emotion (Figure 1). EI provides us with the potential to become fluent in the appraisal of their feelings and the feelings of others. High levels of EI in individuals make them acutely aware of emotional changes within themselves and others and enable them to accurately determine the meanings of various expressions of emotions. Heightened perception of one's own and others' feelings is a primary characteristic of EI. EI is also attributed to the regulation of emotions and emotional labor. As described in the previous section, the regulation of moods and the expression or suppression of certain emotions in social situations demand EI and the utilization of emotional skill. In regulating emotion, EI requires meta-emotion, the equivalent of metacognition in the processes of cognition and reasoning. It takes certain emotional skills to monitor, evaluate, and regulate moods that often control how one feels. For example, it takes levels of EI to seek information and people to associate with to maintain positive self-esteem, moods, and outlooks.

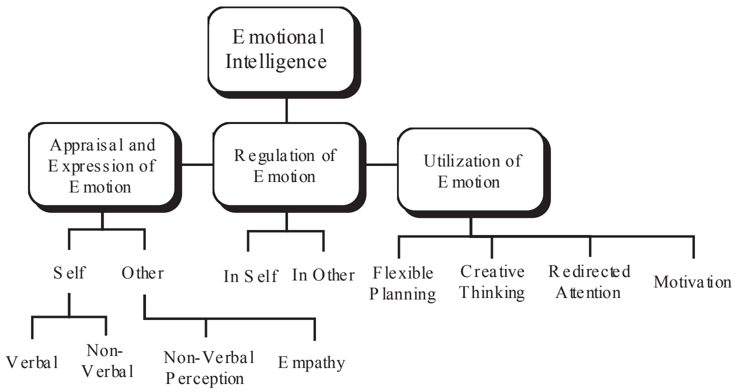
People who are adept at this regulate their moods and feelings to attain specific goals. They work to enhance their and others' feelings to help meet their goals. Of course, it also takes EI to manipulate scenes or to influence others toward selfish ends. EI is necessary in regulating emotional health and in channeling emotions into creativity and motivation. It is necessary to draw on EI for creative problem-solving and to redirect feelings such as anxiety into confidence and motivation. Empathy and understanding of the emotional plight of others require that we harness our EI towards ethical responses.

In technology studies, EI is essential to knowledge and skill development as well as to ethical assessments of design and technology. In the next section, we will shift from theoretical and conceptual issues to instructional issues of emotional development.

Technology, Emotions, and Skills

How can technology teachers take their students' feelings into account when designing curriculum? Teachers can do more than design the elements of anticipation or surprise, or the feelings of motivation, into their curriculum. Technology teachers need instructional strategies that take into account a wider range of emotions, as indicated in the previous sections. In general, emotionally sensitive teaching involves instructional strategies that increase positive emotions and decrease negative emotions. This does not mean that students must always feel good about individual technologies. A positive emotional environment would provide students with the security to express their feelings toward individual technologies. In technology studies, there will be times when students can express their emotions and other times when students will be taught to manage their emotions, or taught the emotional

Figure 1. Emotional Intelligence



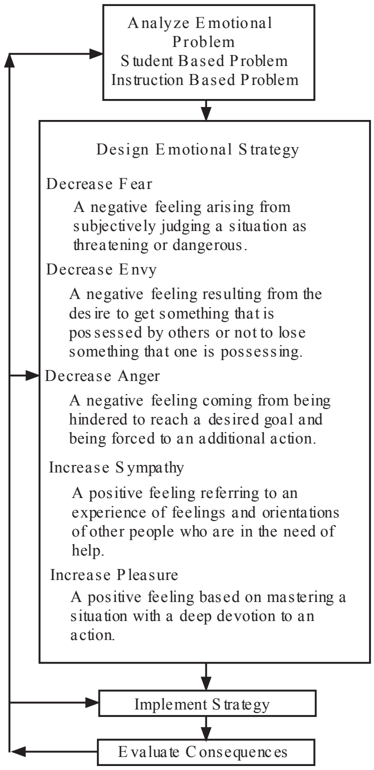
labor necessary to use a certain technology. There will be times when students will feel critical and judicious and other times when students will feel favorable and indiscriminate towards particular technologies.

In general, it is accepted that there are eight primary emotions: joy, sadness, acceptance, disgust, fear, anger, surprise, and anticipation. Each day, teachers deal with this range of emotions across their groups of students. Teachers have responded to an ever-widening range of emotional challenges throughout the past few decades, as familial structures have changed and social assistance has been shifted back to families. Sadness or depression are typically derived from the students' lives outside of the classroom and, short of bullying or mass trauma incited by a crisis, are dealt with through counseling and not instruction. Disgust is an intense feeling that rarely derives from classroom interactions, short of shock strategies. Surprise and anticipation are the emotions of motivation and ought to be an integral part of any instructional strategy. Instructional designers note that five emotions—fear, envy, anger, sympathy, and pleasure—must be dealt with when teaching technology. Fear refers to a negative feeling arising from judging a situation as threatening or dangerous. Envy is a negative feeling resulting from the desire to get something that is possessed by others or not to lose something that one possesses. Anger refers to a negative feeling coming from being hindered to reach a desired goal and being forced to an additional action. Sympathy is a positive feeling referring to an experience of feelings and orientations of other people who are in the need of help. Pleasure is a positive feeling based on mastering a situation with a deep devotion to an action (Astleiner, 2000).

The development of skills with the use of technology requires that emotions be addressed through instruction. The development of skills requires emotional labor and intelligence. Students should feel confident and without jealousy or anger toward each other. They ought to feel sympathetic to each other and derive pleasure or joy from the development of skills. As mentioned earlier, fear will be generated in some students when they are confronted with technology. Jealousies or envy will be generated in others, as they witness differences in abilities and confidence. Some students will grow angry toward technologies that do not respond as planned. Instructional strategies have to be implemented to resolve these feelings in students before progress can be made in the development of skills. Technology can generate considerable distress and students can get trapped in a loop of fear-failure-decreased motivation. The reduction of fears, envy, and anger must be supplemented with an increase of sympathy, success, and pleasure. Reliable instructional strategies for technology teachers were developed by the Austrian researcher Hermann Astleiner (2000).

For technology teachers, a strategy for reducing negative emotions such as fear, envy, and anger and increasing empathy, sympathy and pleasure is crucial to skill development. This is not a disregard for the place of fear, envy, and anger. Rather, the point is that in skill development with technologies these negative emotions

Figure 2. Designing Emotionally Sound Instruction



work against the maintenance of healthy and safe conditions for all students. As we described earlier, technology is emotional and instruction ought to redirect and channel some types of energies into other types. Design for emotionally sound instruction involves a sustained process of working with emotions and helping students to develop emotional and social skills (Figure 2). Students must be assisted in dealing with their emotions with regard to technology. The teaching of emotional and social skills must accompany the acquisition of motor skills. Feelings toward different technologies will differ in individual students, but a general instructional strategy can be used that will make your practice instructionally sound.

All models of emotionally sound instruction acknowledge that there are ranges of feelings that students express while learning design and technology. The challenge is to help them move from anxiety to confidence, from boredom to fascination, from frustration to euphoria, disillusionment to encouragement, and from terror to enchantment (Kort, Reilly, & Picard, 2001). There is an axis on which teachers will find their students scattered in technology studies. On separate points of the axis, individual students will reflect separate emotional sets (Table 1). The concept is *emotional pluralism* and the recognition of a wide range of emotions and their expres-

Table 1. Axes of emotional sets (Adapted from Kort, Reilly, & Picard, 2001)

Axis						
Anxiety-Confidence	Anxiety	Worry	Discomfort	Comfort	Hopeful	Confident
Boredom-Fascination	Ennui	Boredom	Indifference	Interest	Curiosity	Intrigue
Frustration-Euphoria	Frustration	Puzzlement	Confusion	Insight	Enlightenment	Epiphany
Dispirited-Encouraged	Dispirited	Disappointment	Dissatisfaction	Satisfaction	Thrilled	Enthusiastic
Terror-Enrapture	Terror	Dread	Apprehension	Calm	Anticipatory	Excited

sion. For reasons biological and cultural, males and females will emote differently; there will be differences mediated by class, gender, race, and sexuality. Teachers must necessarily accommodate a wide range and hone their skills in recognizing the ways students express their emotions when engaged in technological practice.

Technology, Values, and Skills

When I taught computer aided design during the late 1980s and early 1990s, I began each course by listing the technological values that each student would have to adopt if he or was going to be a successful drafter, designer or CAD technician. These were the values the students had to articulate if they wanted to pass the course:

- Neatness and clarity
- Accuracy and precision
- Flexibility
- Control
- Speed
- Standardization
- Comprehensiveness

I was militant as I pointed to these values on the board and explained the industrial context of drafting and CAD, pounding the podium to get the points across. The fact was that students had already been socialized in the practice of these values. Living in a technological culture, they were immersed in these values as consumers. Now, as far as I was concerned, they were producers and had to articulate the values in their products and skills. When I assessed the processes and products, or skills, of their work in the course, I would write NEATNESS –2 across messy drawings to indicate the emphasis placed on these values. Their drawings and design expressed degrees of neatness, clarity, accuracy, standardization, and comprehensiveness and I marked accordingly, deducting points for misapprehending the importance of these values. Even the CAD drawings could be messy, although neatness and accuracy were automated in the CAD software we used. The values were embodied by the software, written deeply into the programming code. For those who argue that technology incorporates values, or that technologies have particular values built into them, AutoCAD is a primary example. AutoCAD made the values of control, flexibility, and speed explicit. For example, control is automated and much of the students' own locus of control has to be surrendered to the application. The students struggle to give up control and feel extremely frustrated when AutoCAD will not let a command or solution be operationalized. Often, the resolution of this struggle comes down to a contest of wills: the student's will versus the will of AutoCAD. I saw some threatening gestures, but usually the will of AutoCAD triumphed.

My courses were merely a subculture of the larger technological culture in which we find ourselves. The values that I emphasized are articulated daily in our lives. Some say this is unavoidable given that we are basically cyborgs in our close relationships with our technologies. Isolated and disaggregated in individual schools, technology courses, offices and factories, these values may not be a problem. Aggregated across all students and workers of technology, and all factories and offices, these values are concentrated, intensified, and magnified. In fact, some analysts note that modern life is marked by a range of values that are realized when we aggregate our technological practices. In addition to the values that I emphasized, modern technology is characterized by the following values (Sullivan, 1987):

- Power
- Concentration
- Centralization
- Intensification
- Magnification
- Finality
- Persistence
- Scale (expansion and miniaturization)
- Scope (convergence and integration)

We value expansion and miniaturization, for example. Scale refers to size, and contemporary technology extends scale in two directions. Larger and larger technological complexes mark our landscapes, and the concentration of power intensifies our relationships with the environment. Smaller and smaller scales of technology, miniature electronics and nanotechnology, define the trend in digital and biotechnologies. Scope refers to the convergence of technologies and the integration of technologies into every facet of our lives. Scope also refers to the ever-increasing invasive and pervasive characteristics of technology. Technology is characterized by our values of persistence and precision. Technology is persistent, relentless in its increasing effects on our education, health, play, imagination, wars, and work. Technology is increasingly precise and final, but it is also increasingly imperfect.

Theorists of culture maintain that economic values of capitalism intensify the values of technology. Convenience, efficiency, and liberty—free enterprise and freedom of consumer choice—are the seemingly inescapably dominant economic values of our time. Capitalism is dependent on ever-expanding markets of consumers and producers who can respond to the values of convenience, consumer choice, and efficiency. These values are built into the industries that produce the products and services that drive and respond to consumer desires and needs. Not coincidentally, large majorities of people in capitalist societies value convenience, consumer choice, and free enterprise. Again, if isolated in a few individuals, this would not be a problem. When large numbers of individuals and vast majorities of populations adopt the values of convenience and liberty or free enterprise and freedom of consumer choice, problems arise.

Critics counter economic and technological values with sobering thoughts on the rise of rational thinking, threats to class mobility, disability, gender and racial equity, labor, liberty, and unforeseen problems. Critics question popular notions of autonomous and advancing technology, along with technological progress. Notions that technology autonomously advances and, in effect, impacts either positively or negatively on society are reflections of an ideology in which new technology is assumed to be socially progressive.

Critics counter the pervasiveness of technological values in everyday life by providing alternatives to the concentration and centralization of power and scaled-up complexes that characterize modern technology. For example, advocates of "appropriate technology" (AT) prioritize values that are the antithesis of modern technology: simplicity, smallness (small scale), affordability (low-cost) and harmony (with communities and nature). Proponents of AT value diversity, sustainability and the humanization of technology. AT advocates, ecologists, and humanists do not reject technology *per se*. Rather, they note that technologies can be made more ecological and humane by investing technology with natural and human values and by turning technological practice to peaceful and sustainable ends. Over finality, intensification, power, and speed, ecological critics note that technology requires an emphasis on natural values such as diversity, interdependence, permanence and sustainability and humanists advocate values such as community, democracy, patience, prudence and spirituality. Feminists argue for values such as equity, justice, participation, and responsibility. Marxists attempt to orient economics and technologies toward egalitarianism, socialism and the redistribution of power and wealth. Most critics of modern technology argue that new technologies and technological practices are needed, along with a re-prioritizing of values.

Peoples' identities, indeed students' identities are formed and emerge from relations with technologies. For example, many men's and women's identities are linked to their work with technology and skills in the use of certain industrial or information technologies. Many women's and men's identities are linked to household work and skills in the use of domestic technologies. A high value is placed on certain technologies and the skills necessary to use them. The operative qualifier here is "certain" technologies and skills and their value is dependent on who is doing the valuing. Domestic technologies and skills are valued lower than industrial technologies and skills. The medical technologies and skills of nurses are valued lower than the medical technologies and skills of doctors, or the technologies and skills of a virtuoso entertainer in the music industry. The skills of domesticity or craft tend to be taken for granted. And so it goes. The low value placed on sensorimotor skill harkens back thousands of years to Plato, who placed a controlling mind above a subservient body. The low status and value placed on craft skills are reinforced by technology teachers who teach sensorimotor or "hands-on" skills and neglect the cognitive and emotional aspects of design and technology. Similarly, when our identities, or our students' identities, are tied to values of modern technology such as control, expansionism, flexibility, power, precision and speed, we reinforce the very technologies that we may wish to reform. The technologies and skills we value and the values we build into our technologies and reinforce through our identification with them have historical roots and social implications.

Can we expect students to merely adopt values on the basis of authority, peer pressure, propaganda or immersion in capitalist economics? When it comes time to choose from among a range of values in technology, or life in general, how can young people choose their own course of action? Ought we model or teach certain values regarding technology in the labs and workshops? Values clarification, explained in the next chapter, is a technique that deals with the *process* of valuing and challenges to students to formulate and test their values against a range of issues. Character values are addressed in Chapter VII. Dealing with values, whether directly or indirectly, requires that moral choices be made. Teaching with a values consciousness requires that we understand moral reasoning and the processes of ethics.

Models of Moral Development

Students deal with values and technology at their own level of morality. Young children are quite capable of making moral decisions based on their values. In the late 1960s and early 1970s, Lawrence Kohlberg (1975) documented a stage theory of moral development. After working with groups of children, and teenage and adult males, Kohlberg argued that people pass through stages of moral judgment. Kohlberg noted that moral development was a process of growth or progress toward universal principles of morality. However, Kohlberg was quick to note that moral growth was not pinned to biological growth. Young people could advance toward high levels of moral maturity while adults could be stalled in lower stages. Nonetheless, the stages of moral development provide teachers with a road map for analyzing their students' judgments on ethical and moral issues. It provides teachers with an idea of the judgments their students are capable of making. It also gives us an understanding of why some students or people have higher moral standards than others.

Children usually develop through the first two stages and settle into stages three and four. A minority of adults pass into the fifth and sixth stages. The "lower" stages of morality revolve around oneself, then as the morality gets "higher" it includes others individuals and "society." According to Kohlberg (1975), however mistaken, each individual must go through each stage and cannot skip stages. Students progress through social interaction and exposure to individuals that exhibit the "higher" level traits. Moral dilemmas provide people with opportunities to test their beliefs against those of others and thereby learn which moral judgment system yields a more acceptable result.

One criticism of Kohlberg's theory is that the progression from lower to higher levels represents the myth of development and progress in western society. The notion of universal ethics is more culturally specific than Kohlberg suggested. With regards to development, adults do not reach a plateau, but rather pick and choose levels of ethics that depend on situations. Another criticism of the stage theory of moral development comes from feminist psychologists, such as Carol Gilligan (1982). Gilligan noted that Kohlberg's subjects were boys, for the most part. She says that the stages represent male development with an emphasis on the concepts of justice and rights. Female development, she says, is more concerned with negotiation, responsibility and caring. Women must learn to tend to their own interests as well as to the interests of others. Gilligan suggests that women hesitate to judge because they see the complexities of relationships. Rather than apply a universal system of ethics to situations, women tend to look at the specifics of relationships and feelings involved in a moral dilemma. Her three stages of moral development progress from selfish, to social or conventional morality, and finally to a post conventional or principled morality of caring. Kohlberg emphasized the cognitive dimensions of moral judgment and Gilligan brought to surface the emotional dimensions of moral judgment.

Kohlberg's and Gilligan's stage theories are roadmaps and not exact templates of reality. They provide teachers with powerful tools for helping their students with ethical and moral development. Teachers can have high expectations for their students and a clear notion of the moral abstractions that they can handle. Technology teachers, with their responsibilities for design and technology, need to model moral stances that are based on a range of stages in Kohlberg's and Gilligan's theories.

Table 2. Kohlberg's and Gilligan's moral development theories

Kohlberg	**Gilligan**
Punishment and obedience Personal survival—Me against the world	**Selfishness**
Instrumental exchange You scratch my back, I'll scratch yours	**Social or conventional morality**
Interpersonal conformity Good vs. bad	**Post-conventional or principled morality**
Law & order	
Social contract	
Universal principles	

Technology teachers ought to work with their students to demonstrate the range of moral judgments necessary to use and regulate technology. Teachers need to work with their students to understand the ethical and moral judgments that accompany technical skills (Table 2).

As we explained in Chapter I, the affective domain represents a general model of emotional expression and development. In many ways, the affective domain also represents a model of moral expression and development. The affective domain suggests that people express emotions in an increasingly sophisticated way. At low levels, young children merely attend to stimuli and express low level emotional responses, such as satisfaction and dissatisfaction. Young adolescents begin to form and internalize values that they express in their actions. In the upper levels of the affective domain, young adults are capable of organizing a range of different values and emotional responses into value systems. At the upper level of the affective domain, adults are capable of characterizing a value system over periods of time. At the upper levels, individuals are in touch with their own feelings and extremely sensitive to others. Like Kohlberg's and Gilligan's models, the affective domain is a roadmap. The affective domain is not tied to directly to age. People do not biologically evolve or progress to the upper levels. Rather, many adults merely express basic emotions without ever organizing their values into a system that characterizes their behavior. The highest levels nevertheless point toward moral action. If life were a simple as progressive development toward universal morality, there would be no problems. There would be no need for ethics.

Technology and Ethics

The International Society for Technology in Education's (ISTE) third "technology foundation" standard refers directly to ethics: "Students understand the ethical, cultural, and societal issues related to technology." Rather than an ethical standard that states how students ought to act, the standard casts ethics in terms of understanding. It is one thing to understand ethical issues and quite another to act ethically in dealings with technology. Moral action requires both emotion and reason. Moral action means that we make reasoned choices on a justifiable basis. Ethics guides moral action in choices of good and evil, right or wrong, and virtue and vice. Moral actions are those deemed worthy of praise or blame, and affect others or yourself. Ethics is a branch of philosophy that attempts to inform moral action by determining a general basis for making choices and judgments. Ethics guides us in examining our choices and actions and the basis for making and judging these choices and actions. Ethically sound actions and choices, or responsibility, require guidance and education. We have to teach students to act ethically in practical and political dealings with technology.

Many, if not most, of our most serious moral dilemmas today involve technologies we have chosen to produce and deploy. Total war, terrorism, cloning, drugs, global warming, ozone depletion and surveillance involve technology in complex ways. Technology is involved in less popularized yet equally serious moral dilemmas, such as mass consumption, television, and free market capitalism. Even the most mundane decisions such as the food we choose to eat, the air we breathe and the transportation systems we use involve technology and, therefore, require ethical examination. Since the 1980s, specialized fields in applied ethics, such as bioethics, environmental ethics, and computer ethics, suggest the proliferation of new and novel moral dilemmas in technology. There are five general areas which implicate technology in moral dilemmas (Pecorino & Maner, 1985):

1. Technology may *aggravate* certain moral problems (e.g., creating new avenues for infringements on rights).
2. Technology may *transform* familiar moral problems into analogous but unfamiliar ones (e.g., copyright problems were transformed by file sharing on the Web).
3. Technology may *create* new problems that are unique to realms of action (e.g., robots displacing workers in manufacturing).
4. Technology may *relieve* existing moral problems (e.g., built-in breathalyzer in vehicle ignition relives dilemma of drunk driving).
5. Technology may *consolidate and aggregate* a range of moral problems (e.g., genetic engineering allows us to prevent certain diseases, control behavior, identify criminals, etc.).

Our choices to create or use a particular technology are moral choices. Are we free to choose among alternatives based on ethical analysis? Whether it is a particular technology that destabilizes ecology and society and undermines traditional moralities, or whether it is the way that humans use these technologies is a moot point in ethics. Ethics means that we examine possibilities and generate a sound basis for choices.

Morality means that we make decisions on sensitive issues and align ourselves with certain causes. We make moral decisions based on five possible approaches (Edgar, 1997):

- Base moral decisions on feelings and intuition (emotivism).
- Make moral decisions by avoidance or procrastination.

- Make moral decisions by passing the buck. Find a scapegoat to blame for the situation or decision. Go by the book by appealing to authority (e.g., boss, expertise, courts, law). Or follow the crowd and conform to the norm.
- Base moral decisions on caring, sympathy, or love.
- Base moral decisions on a rational criterion.

Of course, there is no magical formula for making moral decisions. Ethics does not divine the right choice or the answer for safe moral action. In technology, we cannot opt for the fifth approach (rational decision making) by simply acting in our own best interest, regardless of other considerations. This is rational egoism. Nor can we make decisions simply by generating a balance sheet of positive and negative impacts to guide our decision. This is consequentialism.

Consequentialism means that consequences alone should be the basis for moral decisions. It means that an action is morally good or right if the consequences of the action are more favorable than unfavorable. Hence, ethical conduct is determined solely by a cost-benefit analysis of an action's, or a technology's, consequences. Simply tally up the good and bad consequences of an action or technology and assess whether the good outweigh the bad. This is the simplest form of technology assessment (Chapter V). Consequentialism holds individuals responsible for the actions whether the consequences were intended or unintended. But it is also an "ends justify the means" type of ethics and inadequate for technological decision making. Consequentialism demands that we calculate potential consequences before acting, yet we can end up to be slaves to utility. Utilitarianism means that we judge an action or technology based on a calculation of the "greatest good for the greatest number." We decide on an action or technology that will provide the greatest happiness or pleasure for the greatest number. Simple utilitarian or majoritarian ethics, or what is good for the greatest majority, are ineffective in making technological decisions. Under majoritarian rule, it becomes difficult to sustain the rights of minorities and the underprivileged in the world. Although there is nothing ethically wrong with this, consequentialism tends to emphasize prudential over moral action. We calculate our decisions and actions to avoid risk.

The other option in ethics is to act on a basis of duty and obligation toward principles and rules, higher spirituality or an intuitive sense of what is good and right. Deontological ethics emphasizes intentions over consequences. What is right or wrong is based on our intentions since consequences are beyond our control. We hold individuals responsible for their intentions, where consequentialism and utilitarianism tend to absolve individuals from responsibilities for consequences. Our conscience and good will ought to be our guides, says deontology.

An ethics that is based on the principle that we should always maximize the goods we want or those goods we think are good for all, unless tempered with justice, will be blind to an equitable distribution of these goods (Ferré, 1988). Privilege and duty go hand in hand. Moral obligation means that we adopt the principles of three golden rules: (1) Do not do unto others what you would not have done to you (Principle of Maleficence). (2) Do unto others as you would that others do unto you (Principle of Beneficence). (3) Weigh actions by what is fair (Principle of Justice). These are summarized as "do no harm," "try to create good," and "be fair."

Moral decisions cannot solely be made on scientific or technical reasoning. An automatic default to authority undermines democracy and a basis for technology studies. Ethics and emotions must play a vital role in technology studies. We have to help our students *understand* consequentialism and utilitarianism, as well as *feel* the weight of moral obligation. We actually have a moral obligation to our students, to help them take responsibility for their technological decisions. Philosophers of technology, such as Carl Mitcham (1996), say that we have three choices in making technological decisions. We can

1. Assume that the problems are so complex that they must be left to the experts, that is, to scientists, engineers, and ethics counselors;
2. Insist that these problems must be handled by the public, even though the public often lacks adequate technical knowledge or sufficient reflection on the ethical issues involved, because this is what our established values require; and
3. Strive to create an informed public that works with technical professionals and ethics counselors to reach informed decisions.

This last option is where technology studies comes in. Informed decision making in technology requires that ethics be taught and explored with students at all grade levels. Informed decision making means that we pay attention to our mission in technology studies to resensitize students to their technological decisions and surroundings. Ethics speaks to the heart with reason, and there is nothing wrong with that.

The controversial issues and values clarification methods explained in the next chapter are essential to assist students in their ethical decision making. In general, an ethical analysis of technological decisions ought to proceed as follows (Edgar, 1997, p. 74-75):

1. Assess the relevant facts of the technologies of interest. Establish the facts of the technology as best as you can. (e.g., here are the facts of the automated telephone dialer- autodialer)
2. Identify the fundamental ethical principles of the technology and keep them clearly in mind. Consequentialist ethics will establish a cost-benefit analysis. Deontological ethics will establish prior principles and obligations (e.g., au-

todialers express rights to free speech; invade privacy; generate junk calls, etc.)

3. Identify which disputes over the technology are concerned with means to an end and which are over the end itself (e.g., disputes over the autodialer itself or over access of private businesses to individuals).
4. Deliberate as is relevant and encourage students to make a decision and act.

As Kohlberg and Gilligan found, young children have no problem with ethical reasoning, emotivism, and making moral decisions. Teachers may have to use techniques that allow students to distance themselves from the issue, where the process takes precedence. For older students, the processes of ethical reasoning and emotivism ought to move students from dualities to commitments. Somewhat like Kohlberg and Gilligan, William Perry (1970) and Jane Loevinger (1976) created two models to help teachers give direction to their students' ethical reasoning (Table 3). Kohlberg's and Gilligan's models deal with growth in longer frames of time. Perrys' and Loevinger's models deal with positions in the span of an issue. These are models and goals to give direction to teachers.

Table 3. Perry's (1970) and Loevinger's (1976) ethical reasoning stages

Perry	**Loevinger**
Basic duality (Issue is either right or wrong)	**Impulsive** (Ignores rules and ethics)
Multiplicity (Recognizes options)	**Self-interested** (Calculates immediate advantage)
Relativism (Tolerant of options and choices)	**Conformist** (Obedient of rules and authority)
Commitment (Acts on commitment, accepts responsibility)	**Conscientious** (Self-critical and responsible)
	Autonomous (Tolerant)
	Integrated (Committed to justice)

Technological decision making has gotten increasingly complex and contingent on ethical analysis. The infringements on our privacies and rights that we can tolerate and cannot tolerate in technology are dependent on our ability to make sound ethical analyses. For example, the fundamental liberty to pursue a livelihood is threatened by technologies of automation that governments support and regulate. The tomato picking machine developed at the University of California in the 1990s was responsible for the elimination of 32,000 tomato picking jobs. The question is whether the infringements on the rights to a livelihood were justifiable, even if the technology was profitable and promised a net benefit to society (Consequentialism and utilitarianism). In technology studies, emotions, knowledge, and skills are empowering. Perhaps there is no greater need than for students to learn to use their skills in ethical ways.

Skill Acquisition

As we acknowledged, cognition, emotion, and action are inseparable. Ethics are inseparable from technical skills. Indeed, do not underestimate the role of cognition, emotion, and ethics in the process of skill acquisition. As we will explain in more detail in Chapter VI, cognition, emotion, judgment and action are interdependent. Many researchers and teachers continue to make the false assumption that emotion, ethics, and cognitive reasoning are simply applied to the development and use of technical skills. They falsely assume that the relationship between emotion, knowledge or judgment and technical skills is application. They assume a priority of knowledge over technical skills. Our task here is to dispel this false assumption. Emotion, knowledge, judgment, and technical skills develop together and are inseparable in experience and practice. In this chapter and the last, we described the articulation and organization of knowledge, emotion and judgment. In this section, we describe the acquisition, articulation, and organization of technical skills.

There are four general types of skills: cognitive, emotional, social and sensorimotor skills. We described a range of cognitive skills in the last chapter. In Chapters V and VII, we will discuss problem-solving and social skills. Some refer to emotional and social skills as "soft skills." Many theorists argue that the acquisition of "hard skills" or technical skills was the essence of industrial education and educational technology. The balance of cognitive, emotional, social and technical skills is the essence of technology studies (head, heart, hand, and feet). Today, technology educators must be prepared to assist students with a wide range of skills.

As we indicated, while technical skills are inseparable from cognition and emotions, they are typically characterized by fine motor skills. First and foremost, motor skills are learned, and distinguished from innate capacities and abilities. Individuals may have a capacity or capability to do something requiring skills, but cannot do it because the necessary skill was not learned. Sensorimotor skill can be simply defined as "a particular application of dexterity" or "the integration of well-adjusted muscular performances, rather than a tying together of mere habits" (Pear, 1927, p. 480-81). Manipulative or motor skill is characterized by motor responses to perceptual awareness and evaluation of a specific situation. Skill involves motor responses to what individuals *perceive* through their senses, as well as what they *conceive* through their minds. But our connotation of skill emphasizes perception and motor control through the senses. Like emotion, sensorimotor skills typically refer to the body and physical performance. Sensorimotor skills most commonly refer to the hand, feet, and coordination between. Skill refers to an overall *combination* of reactivity, bodily orchestration, precision, vocalization, and dynamism (Figure 3). Skill refers to the *quality of a performance* over real space and time.

According to Gardner, skill requires the integration of a wide range of intelligences: bodily-kinesthetic, logical-mathematical and spatial intelligence converge in events that require skill. Skill in this regard is analytical and spatial coordination of one's own or others' physical movements. This definition adopts the premise of *kinesthetic pluralism*, or the recognition of a wide range of the expression of physical skill. Kinesthetic pluralism helps us recognize the value of the wide range of skill articulated in athletics, dance, drawing, construction, engineering, communication, design, health, music, painting, and production. This concept is essential in justifying the role of technology studies in the schools (Chapter VII). Craft and technological skill is an essential domain for skill expression in the schools and, of course, the economy.

Figure 3. A Taxonomy of Motor Skills (Powell, Katzko and Royce, 1978)

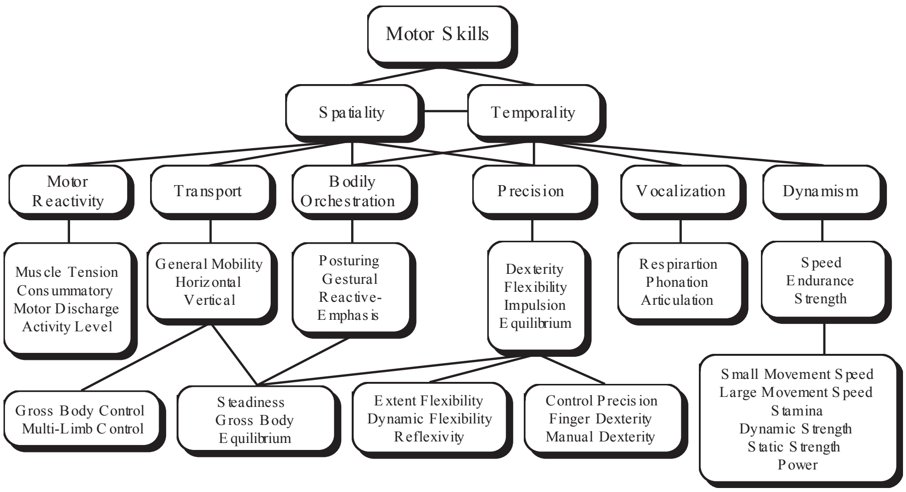


Table 4. Aims of skill acquisition (Adapted from Dreyfus, Dreyfus, & Athanasiou, 1986)

	Novice	Advanced beginner	Competent	Proficient	Expert
Aim	Accuracy and acceptance	Accuracy and independence	Fluency and independence	Fluency and demonstration	Characterization

Three general prerequisites to motor skill acquisition are crucial. The first prerequisite is motivational climate. Teachers must attend to emotionally sound instruction, as described earlier. Students must be provided with a relevant reason for developing particular motor skills and this must translate into motivation. A climate that increases trust and reduces competition is necessary, and students should be encouraged to focus on performance goals rather than outcome goals. A second prerequisite is balance and coordination. In addition to establishing a motivational climate, an aim of teachers who are interested in the development of physical skill is to assist students to develop coordination and guide them towards sensitivity to their movement. Sensory awareness relates to body and limb positioning and velocity as well as the balance of relaxation and tension during movement. Some students will possess this coordination and sensory awareness while others will have to be provided with opportunities and exercises to develop coordination. A third prerequisite is that procedures are articulated

There are four aims of motor skill acquisition, whether it be skill in technology, dance, music or sport. The aim for novices and advanced beginners is accuracy and acceptance. They will aim for achieving accuracy in required tasks, whether by imitating expertise or by transfer from one situation to another. They will also aim to establish acceptance and independence in a culture of practice. Competent and proficient students will aim for fluency and retention of skills. Fluency relates to a high rate of fast, accurate, and automatic motor responses to situations. At these stages, individuals aim to demonstrate their independence and fluency. The aim for experts will be total adaptation to wide ranges of circumstances as well as characterization and identification with abilities (Tables 4, 5). The progression from novice to expert correlates with the development of procedural knowledge described in the previous chapter. The progression of procedural knowledge is from directions to rules of thumb to strategies for fluent, autonomous action.

Teachers can assist novice students in the process of skill acquisition by attending to two basic models (Table 6). In their psychological model, Osborne and Matulis note that the first step in skill acquisition involves perception: the analysis of the task, the formation of goals, the generation of motivation and mental rehearsal. Students must be provided with adequate time to think and talk about the task, and to set goals for themselves. The next step involves the performance of the task. The performance of the task and the final step in the process of skill acquisition involves emotional, mental, and motor responses. Hence, the teacher must also provide adequate time for students to re-analyze and reflect on how they performed. Feedback, both self-reflective and teacher-driven, is essential for students to develop from novice to advance and competent stages.

Skill acquisition is not merely dependent on psychological processes. Rather, skill acquisition is embedded in cultural norms and practices. Lave and Wenger argued that skill acquisition is dependent on the "communities of practice" that accommodate kinds of skill acquisition (Table 5). The way that students acquire skill and the type of skill they acquire are dependent on an array of factors that are more cultural and social than psychological. The cultural model is captured somewhat in the apprenticeship model of skill acquisition. Apprentices are immersed in a community where they learn the norms and practices of their craft or trade. Skill acquisition begins with the immersion of students into a culture—discourses, emotions, languages, norms, practices, and technologies. These norms and practices are picked up informally, through interactions and observations, and formally through demonstrations. The apprentices practice their skills, express the norms of practice, and are provided with a range of informal and formal feedback from their peers and instructors. The entire process is one of enculturation and socialization, as well as cognition and emotion. The cultural model is much more inclusive than the psychological model of skill acquisition. It models the acquisition of destructive norms and practices along with those that are constructive. Students will acquire communication and social skills ("soft" skills) along with fine motor skills ("hard" skills). They will find themselves struggling to be accepted, or to reject, the norms of their communities of practice. In some technological fields, the culture is deliberately masculine and comes with all the trappings of masculinities, including competition, sexism and heterosexism. In other technological fields, the cultures are deliberately feminine

Table 5. Psychological models of skill acquisition

Psychological (Osborne & Matulis, 1988)	**Cultural** (Lave & Wenger, 1990)
Analysis of task, goal formation, motivation, mental rehearsal	Immersion
	Demonstration and interaction
Performance or practice	Practice and expression
Cognitive, emotional and motor response to feedback & stimuli	Feedback

and carry their own trappings. Students also acquire and reconstruct the values of the communities of practice, including the values placed on skill. Some analysts suggest that in technology-intensive cultures, students tend to acquire the fetish for skills and tools that marks practice in these cultures.

However, there is a difference between work-site cultures and school cultures. School cultures provide the ethical grounds for redressing the work-site communities of practice that maintain troubling values. For example, there is no reason that schools have to reproduce the values of a construction site where masculine values such as competition and abrasive communication accompany skill acquisition. In an information technology class in schools, there is no reason to reproduce the values of a software production site where speed, secrecy and paranoia accompany skill acquisition. Schools are sites where a community of practice that values equity can be can be established. As indicated, emotionally sound instruction ought to underwrite skill acquisition in schools.

We gauge the level of skill acquisition in our students and peers by assessing the way they perform during a skilled task or challenge. Rather than judging products, such as the precision, speed or stability of objects, it is much more helpful to assess the performance of individuals to gauge their stage of skill acquisition. People will process elements of a situation differently, depending on their stage of skill acquisition. Novices will focus on individual elements of a situation where someone in a competent stage will process a range of elements simultaneously. Novices approach procedures much differently than proficiently and expertly skilled individuals. In a skilled situation, novices require explicit directions and rules and will adhere to only the objectively defined rules or context-free *features*. For example, a novice learning to drive a standard transmission (stick shift) vehicle will be given context-free rules such as shift from first to second when the speedometer reaches 10 mph or 15 kph. Merely following these directions will often result in poor performance. Shifting on a hill or a heavily loaded vehicle will require an adjustment to the rule. The next stage of skill acquisition requires directions as well as context (Dreyfus & Dreyfus, 1986, 1999, 2004).

As the novices gain experience, instruction can provide meaningful *aspects* in addition to rules. For example, advanced beginners learn to recognize situational aspects (engine sounds) and rule-of-thumb such as shift up when the engine is racing and down when it sounds like it is straining. Advanced beginners are overwhelmed with information and fear, however, and progression to another stage requires rules-of-thumb and strategies to restrict themselves to few relevant features and aspects. Experience proves that there are a vast number of situations in which skills are used and they differ in quite subtle ways. For example, driving conditions change from day to evening, from dry to wet, and virtually from street to street. Competent drivers judge what plan or strategy to adopt from condition to condition. Off-ramps of freeways require judgments on when and whether to press the brake to maintain safe speeds. Often, a feel for the road requires that a competent driver maintains a speed through a curve rather than a choice to brake in the curve. Where the advanced beginner falls back on tried and true maxims, the competent driver is fully invested in this situation and demonstrates an emotional investment in the choice of action. He or she can no longer rely on specific directions and rules and feels confident about decisions made from situation to situation. At the proficient stage, intuitive responses begin to replace guess-work and reliance on rules-of-thumb and rules. Proficient drivers have accumulated a large repertoire of rules, rules-of thumb and strategies to draw from. On approaching a curve on a rainy day, a proficient driver may feel that s/he is going dangerously fast. He oe she decides in the situation whether to apply the brakes or reduce the speed by slowly easing up on the accelerator. The expert not only sees what needs to be achieved but also immediately what to do. Experts attain the ability to make more subtle and refined discriminations and ultimately immediate, intuitive situational responses. The expert driver will not be suspended in decision; he or she will intuitively do what needs to be done in a curve on a rainy day. Where novices and advanced beginners will exercise minimal judgment over skilled task situations, those in proficient and expert stages exercise conscious, deliberate judgment over tasks and automatically act on their judgment (Table 6).

The progression through fives stages of skill acquisition, from novice to expert, relates directly to the psychomotor domain described in Chapter I. The psychomo-

Table 6. Stages of skill acquisition (Adapted from Dreyfus & Dreyfus, 1986, 1999, 2004)

	Novice	**Advanced beginner**	**Competent**	**Proficient**	**Expert**
Processing elements of a situation	Sees only those that are clearly and objectively defined	Perceives similarity with prior examples	Reflects upon various alternatives to goal	Intuitively organizes and understands task without decomposing it into component features	Intuitively organizes and understands task without decomposing it into component features
Rules of behavior & decision-making	Follows clear procedures and rules	Transfers from one situation to another	Analytically calculates choices that best achieve goal	Consciously focuses on choice that best achieves intuitive plan	Acts in an unconscious automatic, natural way
Exercising judgment	Minimal	Minimal	Consciously deliberates	Acts based on prior concrete examples in a manner that defies explanation	Unconsciously does what normally and ethically works

tor domain is a model of skill acquisition over a sustained period of time. There are actually two models of the psychomotor domain, one constructed by Dean Hauenstein (1972, 1998) and one by Ruth Simpson (1966) (Table 7). Their psychomotor domains model the processes of long term skill acquisition. The psychomotor domain does not provide a model of situational skill acquisition, or a model of what a person does within a skilled task or a skill challenge. The domain refers to long term skill acquisition and allows teachers to gauge where their students are along a spectrum. The psychomotor domain provides a more detailed gauge than does the general stages of skill acquisition (i.e., novice—expert). According to Hauenstein's model, students move from simple observation, imitation, manipulation, performance and perfection. In Simpson's model, students move from simple perception to mental readiness, guided response, habitual response and automatic performance. The psychomotor domain, along with the models of situational skill acquisition, provides teachers with powerful tolls for planning instruction in and enhancing skill acquisition.

Enhancing Skill Acquisition

What can teachers do to maximize or enhance the acquisition of skills and assist their student to progress from novice to competent? First and foremost, teachers should not underestimate the role of cognition, emotion and ethics in the process of skill acquisition. Cognition, emotion, and ethics must be taught as integral to

Table 7. Models of skill acquisition over sustained periods of time

Hauenstein (1972)	**Simpson (1966)**
Observing	Perception
Imitating	Set (mental readiness)
Manipulating	Guided response
Performing	Mechanism (habitual response)
Perfecting	Complex overt response (automatic performance)

skill acquisition rather than as sub-features of technology studies. Second, motivational climate and emotionally sound instruction are central to skill acquisition. Techniques for establishing a climate for appropriate classroom behavior are explained in Chapter XI. In the following chapter, we will address learning styles and techniques that allow us to attend to differences among learners who have a range of preferences in the way they acquire knowledge, values, and skills. Specifically, teachers can enhance skill acquisition by observing the following principles (Osborne & Matulis, 1988).

1. Readiness and personal motivation heavily influence the quality of the early stages of skill acquisition.
2. The performer's estimates of failure or success in a given task heavily influence perceived levels of readiness and motivation.
3. Encourage students to set attainable goals for themselves for the completion of the task.
4. Always provide a context for the skill to be developed.
5. Females tend to perform better in the verbal mode rather than the visual spatial mode of readiness (Need time to talk about what they will do).
6. Provide models of quality performance *via* teacher demonstrations. Imitation is a vital element for students.
7. Demonstrate procedures with clear directions, if-then rules and sequential steps.
8. Allow for rehearsal for students to articulate and develop procedural knowledge.
9. Distributed practice sessions are more effective than mass sessions.
10. Mental practice enhances skill acquisition and leads to greater retention.

Accurate and frequent feedback is especially critical during the early stages of skill development. In Chapter II, we explained effective feedback techniques that ought to guide motor skill acquisition feedback (see also Chapter IV). In addition to our general principles of feedback, such as sandwiched responses to students, there are techniques that are specific to motor skill acquisition. Instruction in skill acquisition involves feedback that is derived from the performance by the students as well as feedback provided by the students. According to all models of skill acquisition, varied feedback is absolutely necessary for students to move from novice, to advanced beginner, to competent, proficient and expert. **Feedback** in skill acquisition may be:

1. **Intrinsic:** Feedback obtained through the senses of the performer, such as resistance, weight, or smoothness.
2. **Extrinsic:** Feedback provided by an outside source such as a teacher, peer, or videotape.
3. **Concurrent:** Feedback received during skill performance.
4. **Terminal:** Feedback received at the conclusion of the performance.

To assist in the **transfer of skills**, from the labs and shops to situations outside the schools for example, there are techniques that teachers can emphasize. The key to transfer lies in the instruction of generalizable aspects of skill performances, varieties of applications, depth in skill acquisition, and task to task similarities. Specifically, teachers should observe the following principles for the transfer of skills with their students:

1. Focus on the underlying principles of the skill so that broadly applicable generalizations can be identified.
2. Use a variety of techniques and examples to illustrate the principles.
3. Seek a high level of learning and performance in the task to be transferred.
4. Stress similarities between the original task and the task in which skill transfer is sought.

Projection and Reflective Practice

In the previous chapter, we dealt with cognitive issues and the organization of knowledge. We acknowledged that knowing was always accompanied by feeling and doing. We began this chapter by describing the relationships between technology and emotions. We suggested that action, cognition and emotion are inseparable. We asked whether technology itself has emotions invested within its very logic and whether humans merely emotionally respond to technology, a cold, emotionless fact of modern life. We provided a number examples to demonstrate that contrary to popular assumptions, technology and emotions have quite fascinating interrelations. Emotional labor demonstrates quite readily that a wide range of emotions are necessary to the design and use of technology in the workplace. Emotional labor is also integral to skill acquisition at all levels, from novice to expert. A framework was provided for teachers to use in designing emotionally sound instruction in technology studies. Emotion and cognition are at the root of ethical judgment in technology. Kohlberg's and Gilligan's theories of moral development provide insight into how ethical judgment is acquired, recognizing that developmentalism has its shortcomings. Teaching ethical judgment in technology studies requires that we have a range of methods, such as values clarification and controversial issues analysis, to adequately address values in design and technology. The next chapter deals with these two methods and comprehensively outlines a number of others that are essential to technology teachers.

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Chapter IV

Instructional Methods and Learning Styles

Introduction

How do we factor the variability of students into our instructional methods? All students are different, and yet there are many commonalties from student to student. Should students simply design their own education, an education that theoretically would be tailored to their needs? Should students be left to their own desires and needs, as Rousseau advocated in *Emile* in the late 1700s and as A. S. Neill advocated in *Summerhill* in the 1960s? Or are there ideas and methods that all students should simply endure for the good of the social system? We have learned quite a bit about accommodating the variability of students through research into instructional methods and learning styles. If we vary our methods, we have learned, we accommodate a wider range of learning styles than if we used one method consistently. Teaching methods are the complement of content, just as instruction is the complement of curriculum. Technology teachers tend to over-use projects and problems, ignoring the options and opportunities that the balance of teaching methods offers. In this time of global hazards and changes in our lives wrought by technology, it is essential that technology teachers maintain a refined sense of how to teach about controversial and sensitive technological issues. It is essential that technology teachers have a command over values clarification methods as well as demonstration and project methods. Given that technology teaching methods are often research-driven, twenty-two research methods are outlined in this chapter. Forty-one teaching methods are defined and five that are central to technology studies are explained in detail. The chapter concludes with detailed sections on the relationships among instructional methods, personalities, and learning styles.

Instructional Systems

Think *systemically* about instruction. Systems involve relationships, conditions, processes, causes, effects, and feedback. To identify a system, we must demarcate where one system ends and another begins. In education, as in ecosystems, this is done somewhat arbitrarily. For example, if we identify and focus on an instructional system, we necessarily bracket out the learning system. We make some system components visible and leave others invisible. We identify an instructional system at the peril of ignoring other systems or bracketing too narrowly. What is involved in the process of instruction? What are the essential components of instruction? Instructional systems involve decisions related to what will be taught, how it will be organized for learning and how learning will be assessed. For analytical purposes, it is necessary to identify what students and teachers do within the system. It is important to address individual components of the system. While there are components that are overlooked, the next diagram generally represents an instructional system. Events of instruction, such as an activity, demonstration, or presentation require that teachers attend to all of the components within the system. Instructional planning unfolds quite procedurally, but not necessarily in a linear fashion (see Chapter IX).

It is important to grasp the scope of an instructional system and its complexities along with interrelations among its components. When we alter a component within the system, we change the conditions for all the components. We alter the process of instruction. A third is that while we may isolate an instructional system, we do not eliminate the interrelations among this system and others. When we alter instructional systems, we alter learning systems as well. Instructional systems are not built in stone. They are malleable. Hence, if there are problems and issues that are systemic rather than consequential to the system, the system can be altered. These are the most important lessons to take from our recommendation to think systematically about instruction.

In the first chapter, we approached the subject of communication and instructional planning holistically. Invoking our cycle of experience, we suggested that the best way to learn how to teach is to teach. The best way to learn how to teach technology studies is to learn how to demonstrate. Demonstrations involve all of the components of an instructional system. Instead of breaking down a demonstration into separate components, we approached it as a whole entity. However, we also dealt with instructional objectives in an isolated, albeit focused, way. In the remainder of this chapter, we address instructional methods, teaching styles, and learning styles.

Teaching Methods

General models and families of teaching methods are guides for designing educational activities, environments, and experiences. They help to specify methods of teaching and patterns for these methods. Instructional strategies, or teaching methods, depend on a number of factors such as the developmental level of students, goals, intent, and objectives of the teacher, content, and environment including time, physical setting, and resources. Imagine a course that challenges teachers to meet a number of objectives. A single method cannot meet all of our goals nor can a single method accommodate all learning styles at once. For example, demonstrations or projects are effective for meeting some goals but ineffective for meeting others. So we need a toolbox of methods, not merely a single tool.

In the most general terms, there are four or five different models of instructional strategies or teaching methods. Having spent years in schools, you will recognize each and probably have strong preferences for one or two models.

- **Didactic:** Direct teaching; Verbal and typically in the form of a lecture or presentation.
- **Modeling:** Direct teaching; Visual and typically in the form of demonstration and practice.
- **Managerial:** Indirect or Interactive teaching; Facilitation, individualization, and group management.
- **Dialogic:** Indirect Interactive teaching; Socratic Technique of dialogue, questions, and thought provocations.

In the direct instruction models, the teacher imparts knowledge or demonstrates a skill. In the indirect instruction models, the teacher sets up strategies, but does not teach directly; the students make meaning for themselves. In the interactive instruction models, the students interact with each other and with the information and materials; the teacher is organizer and facilitator. Experiential Learning models mean that the students experience and feel; they are actively involved. In independent study models, the students interact with the content more or less exclusive of external control of the teacher. Some theorists prefer to reduce these to three general methods: Transmissive, transactive, and transformative teaching. Transmissive teaching, or direct instruction, means that the teacher delivers *status quo* content *via* some method such as lecturing or demonstrating. Transactive teaching, or indirect instruction, means that the teacher and students arrive at *status quo* content to be learned though transactions and dialogue. Transformative teaching, or a combination of direct and indirect instruction, means that the teacher and students reject status *quo content* and focus on a transformation of themselves or their world.

These general models help us to classify teaching methods and simplify our discourse for conversing about them. We also group methods by their "family" affiliations. Some methods lend themselves to encouragement of social interaction in students. Other methods encourage information processing and some facilitate behavioral modification. Still others support intrapersonal and interpersonal development. Each of these families offers different approaches to teaching, respond to different objectives and goals, and yield different results in students.

The following list provides definitions for a variety of different methods, including most of those listed above (Cruikshank, Bainer, & Metcalf, 1999). Every method has advantages and disadvantages. For example, cooperative learning allows for the participation of everyone, but the groups often get side tracked. Role playing

Table 1. Families of teaching methods (Adapted from Joyce & Weil, 1980, 1996)

- **Social interaction family:** Emphasizes the relationship of the individual to society or to other persons. Gives priority to the individual's ability to relate to others.
    - Partner and group collaboration
    - Role playing
    - Jurisprudential inquiry
- **Information processing family:** Emphasizes the information processing capability of students. Gives priority to the ways students handle stimuli from their environment, organize data, generate concepts, and solve problems.
    - Inductive investigation & inquiry
    - Deductive investigation & inquiry
    - Memorization
    - Synectics (techniques for creativity)
    - Design and problem-solving
    - Projects & reports
- **Personal family:** Emphasizes the development of individuals, their emotional life, and selfhood. Gives priority to self-awareness.
    - Indirect teaching
    - Awareness training & values clarification
    - Role modeling
    - Self-reflection
- **Behavioral modification family:** Emphasizes the development of efficient systems for sequencing learning tasks and shaping behavior. Gives priority to the observable behavior of students.
    - Direct instruction (demonstrations & presentations)
    - Anxiety reduction
    - Programmed instruction
    - Simulations

introduces a dramatic problem situation, but some students are too self-conscious to project themselves into the situation. Large group discussions pool ideas and experiences from the group, but a few students may dominate. Values clarification allows students to clarify their values in a safe environment, but some students may not be honest in this environment. Projects allow for self-directed problem-solving and creativity and take advantage of intrinsic purposes, but too much focus is placed on the product and too little on the process. There is a pedagogy (art and science of teaching) to each method that is beyond the scope of this book. In the first chapter, we explained the pedagogy of demonstrations and presentations. In the next chapter, we will address problem-solving and design briefs. Chapters six and nine will deal with activities, projects, and units. Think about your teaching methods and the range that you use. Practice a variety, if only to make your practice interesting.

In the next few sections, a summary of some of the most commonly used methods in technology studies is provided. Other common methods are described in other chapters as indicated in the previous definitions.

Teaching Methods (Cruikshank, Bainer, & Metcalf, 1999)

1. **Academic games or competition:** Learners compete with each other one to-one or team-to-team to determine which individual or group is superior at a given task such as "spelldowns," anagrams, technology trivia, Odyssey of the Mind, or project competition. Commercially available, academic computer games are also very popular.
2. **Activity:** A general teaching method (e.g., problem-solving, design challenge, field trips, role playing) based on planned, purposeful involvement of students.
3. **Brainstorming;** Order to generate creative ideas, learners are asked to withhold judgment or criticism and produce a very large number of ways to do something, such as resolve a problem. For example, learners may be asked to think of as many they can for eliminating world hunger. Once a large number of ideas have been generated, they are subjected to inspection regarding their feasibility.
4. **Case study:** A detailed analysis is made of some specific, usually compelling event or series of related events so that learners will better understand its nature and what might be done about it. For example, learners in a technology lab might investigate the wear and tear of skate boarding on public works. Another class might look at cases of digital technologies and privacy.
5. **Centers of interest and displays:** Collections and displays of materials are used to interest learners in themes or topics. For example, children may bring to school and display family belongings that reflect their ethnic heritage. The

intention may be to interest the class in the notion of culture. Or, the teacher might arrange a display of different devices used in measurement to prompt interest in that topic.

6. **Colloquia:** A guest or guests are invited to class for the purpose of being interviewed in order to find out about the persons or activities in which they are involved. Thus, a guest musician might serve as a stimulus for arousing interest in music and musical performance.
7. **Contract:** Written agreements entered into by students and teachers which describe academic work to be accomplished at a particular level ill a particular period of time such as a week or month.
8. **Controversial Issues:** An issues-based, teacher-directed method that focuses on controversies. Students are directed through a process that assists them in understanding how to deal with controversial and sensitive issues and clarifies these issues in a group context. Involves critical thinking and discourse analysis (Chapter IV).
9. **Cooperative learning:** Learners are placed in groups of four to six. Sometimes the groups are as diverse or heterogeneous as possible. In such cases, group members are often rewarded for the group's overall success. Student groups might be given a teacher presentation on division of fractions. They would then be given worksheets to complete. Team members would first help and then quiz one another (Chapter IV). See also student team learning.
10. **Culture jamming:** A methods used to empower students to "speak back" to mass advertisements and media images that enforce stereotypes and select representations of individuals or groups. Empowers students to mock or "jam" images of popular culture.
11. **Debate:** A form of discussion whereby a few students present and contest varying points of view with regard to an issue. For example, students could take different positions and debate an issue: "Should rights to free speech on the internet be extended to students in schools?"
12. **Debriefing:** A method used to provide an environment or platform for the expression of feelings and transfer of knowledge following an experience. Debriefing may come at the hands of a tragic event or may be used more generally following an intentionally educational experience. Debriefing relies on the skills of the facilitator to reframe an experience or event to appropriately channel emotions and knowledge toward understanding and transformation.
13. **Demonstration:** A teaching method based predominantly on the modeling of knowledge and skills. A form of presentation whereby the teacher or learners show how something works or operates, or how something is done. For example, a teacher could demonstrate how to use a thesaurus, how to operate a power drill, how to scan an image, or what happens when oil is spilled on water

as when an oil tanker leaks. Following that, students practice under teacher supervision. Finally, independent practice is done to the point of proficiency (Chapter I).

14. **Direct instruction:** A term used to describe explicit, step-by-step instruction directed by the teacher. The format or regimen advocated is demonstration, guided practice, and independent practice. Thus, the teacher might teach a reading, mathematics, geography or technology concept or skill. Following that, students practice under teacher supervision. Finally, independent practice is done to the point of mastery.
15. **Discovery or inquiry:** Discovery learning is used when students are encouraged to derive their own understanding or meaning for something. For example, Students are asked to find out what insulation acts as the best barrier for cold or hot environments. Experiments that are not teacher demonstrations are part of discovery learning (Chapters II, V).
16. **Discussion:** Discussions occur when a group assembles to communicate with one another through speaking and listening about a topic or event of mutual interest. To illustrate, a group of learners convenes to discuss what it has learned about global warming (Chapter IV).
17. **Drill and practice:** A form of independent study whereby, after the teacher explains a task, learners practice it. After Students are shown how to use Ohm's Law, they are asked to make calculations of current, resistance, and voltage.
18. **Feedback:** A semi-formal mode of communicating to students constructive criticism regarding their performance during an activity (Chapter I).
19. **Field observation, fieldwork, field trip:** Observations made or work carried on in a natural setting. Students visit the local museum of natural history to see displays about dinosaurs, or they begin and operate a small business to learn about production and marketing.
20. **Independent study or supervised study:** Described in this chapter, independent study occurs when learners are assigned a common task to be completed at their desk or as a home study assignment.
21. **Individualized instruction:** Any of a number of teaching maneuvers whereby teaching and learning are tailored to meet a learner's unique characteristics.
22. **Installation:** Students present material within a formal structure for displaying audio, multimedia, or visual artifacts.
23. **Module:** A module is a self-contained and comprehensive instructional package, meaning that basically everything that the student needs is in the module. A form of individualized instruction whereby students use a self-contained package of learning activities that guides them to know or to be able to do something. Students might be given a module containing activities intended to help them understand good nutrition (Chapter IX).

24. **Mastery learning:** As a class, students are presented with information to be learned at a predetermined level of mastery. The class is tested and individuals who do not obtain high enough scores are retaught and retested. Those who passed undertake enrichment study while classmates catch up.
25. **Mixed-mode instruction:** A combination of "face-to-face" and online methods.
26. **Online instruction and learning:** A self-directed and automated approach that utilizes hypermedia (internet browsers, etc.) for communication that generally provides independence from the architectural constraints of classrooms.
27. **Performance:** Students act out through dance, drama, music or other expressive forms.
28. **Presentation and lecture:** Students listen to a person who talks about a topic. To illustrate, the teacher, or a guest speaker, tells the class all about the invention of the transistor.
29. **Problem:** A general teaching method and organization of curriculum and knowledge where students work purposefully toward a solution, synthesis, or cause. Often called problem-based learning (Chapter V).
30. **Programmed and automated instruction:** A form of individualized instruction whereby information is learned in small, separate units either by way of reading programmed texts or using computer-based programs (See Online instruction).
31. **Project:** Students work through a series of activities and problems culminating in the completion of something tangible (e.g., artifact, media, performance). A form of individualization whereby learners choose and work on projects and activities that facilitate and support the development of skills and knowledge. Often, learners not only choose topics but also the means of their conduct and production. (Chapters VI, IX).
32. **Protocols:** Learners study an original record or records of some important event and then try to understand the event or its consequences. They might watch a film depicting actual instances of discrimination and then consider its causes and effects.
33. **Recitation:** Students are given information to study independently. They then recite what they have learned when questioned by the teacher. For example, students read about what causes pollution, and the teacher, through, questioning, determines the extent and nature of their knowledge and understanding.
34. **Reports, written and oral**: Individuals or groups of learners are given or choose topics. For example, each may be asked to find out about one planet in our solar system, or about solar powered vehicles. What they learn is shared with other class members by way of oral or written presentations.

35. **Role playing:** Learners take on the role of another person or character to see what it would be like to be that person or character. Thus, a student could play the role of an imaginary student no one likes or a news reporter.
36. **Simulation game:** Students play a specially designed, competitive game that mirrors some aspect of life. For example, they might play the Ghetto Game to find out about the problems and pressures that ghetto dwellers face and to sense how difficult it is to improve one's lot in life. Another commercially available simulation game is Gold Rush (life and adventure in a frontier mining camp). Many simulation games, such as Sim City, are automated.
37. **Simulation:** Learners engage with something intended to give the appearance or have the effect of something else. Thus students may engage in a simulation of the United Nations General Assembly in order to have "first hand experience" with how it works and what its delegates do.
38. **Synectics:** The use of specific techniques to foster creativity in students. For example, the students may be asked to develop metaphors to describe mobility across different terrains (Chapter V).
39. **Tutoring:** A form of individualization whereby either a teacher, or perhaps a fellow student, provides a learner or small group of learners with special help, usually because they are not learning well enough with only conventional instruction.
40. **Unit:** An intentionally designed, integrated, thematic organization of curriculum and knowledge through combinations of demonstrations, discussions, activities, problems, and projects (Chapter IX).
41. **Values clarification:** Teachers lead students through a series of moral and ethical dilemmas, such as birth control or clear-cutting forestry practices, to assist them in clarifying their values and moral choices (Chapter IV).

Controversial Issues

The controversial issues method deals with the processes of critical thinking and working through controversies. As the world gets smaller through the globalization of culture, economics, media, and controversial issues proliferate. As we grow more sensitive to the interdependence of cultures, individuals, races, religions and species, we assume more responsibility for sensitivity when dealing with issues. As technology is made more invasive and pervasive in our lives, it becomes more critical to make wise choices for what we create, buy, or sell. Students at younger and younger ages are finding themselves entangled in Webs of economics, politics, sex, technology, and violence. The controversial issues method will not help us reduce the number of controversies in our lives but it does help us to deal with controversies critically and sensitively.

Controversial issues are quite topical and can typically be directly related to students' lives. Controversial issues are an essential part of the curriculum if the schools are to fulfill their mandate to prepare citizens for democratic participation. Controversies provide students and teachers with opportunities to comprehend, reflect, practice, and make commitments and act. They are crucial for helping students to develop their ethical and moral reasoning and to become critical thinkers. Controversial issues are likely to challenge students' beliefs, values, and worldviews. This can be threatening and confusing, and can cause some students considerable emotional distress. Hence, if controversies are not properly addressed in the classroom, students often resist engaging with the issues because they are angry or feel threatened. What is a controversial issue?

Criteria that characterize a controversy:

- There are competing views and interests.
- People disagree strongly about statements, assertions, or actions.
- There is sensitivity.
- Emotions become strongly aroused.

Controversial issues form around:

- What has happened
- The cause of the present situation
- The desirable ends to work towards
- The appropriate course of action to be taken
- The likely effect of action

Controversies are complex. Working through controversies requires knowledge of what the controversy is about, an awareness of one's own values and a sense of identification with the controversy. Teaching with the controversial method requires balance, disclosure of commitment, and taking a stance without coercion or indoctrination of others. Teachers are responsible for establishing ground rules, moderating any classroom incivilities, moderating one's own and the students' over-attachment to content or an overreaction to criticism. Teachers are responsible for moderating negative thinking and strong emotional reactions in their students. Ground rules are necessary to govern classroom procedures and to moderate the nature of the contributions to understanding the controversial issue. Ground rules should enable the free

Table 2. Tips for teaching controversial issues (Street Law, 2003)

1.	Recognize the general legitimacy of controversy. Controversy is part of society and students must learn to discuss the issues and problems presented.
2.	Establish ground rules for proceeding. Create and agree on effective rules.
3.	Use the framework provided for dealing with controversial issues.
4.	Concentrate on evidence and information.
5.	Represent opposing positions accurately and fairly (balance).
6.	Clarify the issue so that students understand where there is agreement and disagreement.
7.	Identify core issues.
8.	Make the issues concrete before launching into levels of abstraction.
9.	Allow students to question authority (i.e., question the teacher's position).
10.	Admit doubts, weaknesses, and difficulties in your position.
11.	Teach understanding and active listening by re-stating the perspective of others. Have students paraphrase what others said to gain this skill.
12.	Demonstrate respect for all opinions.
13.	Establish a means for closure. Examine consequences and consider alternatives. Do not leave the class suspended in neutrality or inaction.

flow of information in a safe, non-threatening environment. Classroom incivilities include teacher and student behaviors that distort the classroom atmosphere and negatively affect learning. Teacher incivility can include rudeness, prejudice and the neglect of the needs or emotions of individual students or groups of students. Teachers can actually stimulate student incivilities by appearing neglectful of students' welfare. Student incivility can include disruption, rudeness, and distractions during an activity. When using the controversial issues method, teachers must be vigilant about behaviors that stimulate incivilities. Moderating an over-attachment to ideas and an overreaction to criticism will help students move from black-white thinking to complex understandings. Students use a range of strategies to deliberately cling to a certain view. Students will discount information that is not congruent with their opinion or distort and revise this information to become congruent. Teachers must help students keep these practices in check by encouraging a fair analysis of multiple aspects of a controversial issue. Moderating negative thinking and strong emotions involves the reframing of negative thoughts and irrational feelings. Teachers must reframe into positive terms what students say in negative terms. They have to help clarify issues that might underlie irrational feelings (Flinders University, 2001).

The key to the controversial issues method is a framework for handling the controversy (Clarke, 1993). Success depends on whether participants communicate and methodically work through the issue. Werner and Nixon (1990) developed a comprehensive framework for teaching controversial issues that orients the method towards clear communication and critical thought (Table 3). As well as setting the tone as we described, teachers have to assume responsibility for clarifying the issues, arguments, assumptions, and manipulations contained in the controversy itself. They

Table 3. Controversial issues framework (Adapted from Werner & Nixon, 1990)

	What is at issue?	
Identify and clarify central value questions	Identify and clarify central empirical questions	Identify and clarify central conceptual questions
What should be done? What is the alternative? Is X better than Y?	What is the case? What was the case? What will be the case?	What is X? How is X to be defined? What is the meaning of Y?
	What are the Arguments?	
Clarify the value claims	Clarify the empirical claims	Clarify conceptual claims
What is the argument for X? What is the argument against X?	What evidence is there for X? What evidence is there against X?	Does the evidence for X match the argument for X? Does the evidence against X match the argument against?
	What is Assumed?	
What attitudes are assumed?	Whose voice is heard?	What points of view are assumed?
Are prejudice attitudes present? Ethnocentrism? Racism? Parochialism?	Insiders? Outsiders? Experts? Lay public?	Personal? Institution? Region? Academic subject area?
	How are the Arguments Manipulated?	
What groups are Involved?	How are the media involved?	What strategies are used?
What are their interests? What are their rationalizations?	News? Documentary? Internet? Alternative media?	Unfairly attacking opponents? Reducing complex issues? Using loaded language or exaggeration?

have to assist their students clarify the values contained in the issue and their own values effected in response to the issue. The values clarification method is provided in the next section. Werner and Nixon's framework is provided in Table 3.

Controversial issues can be combined with the values clarification method or with sociologics (Chapter V). This method can also be designed into a module (Chapter IX), which is student directed, or a unit (Chapter IX), which combines activities and projects with discussion. Controversial topics in technology studies include: Acid Rain, Alternative Medicine, Cancer & Risk, CFCs & the Ozone, Crime & DNA, Deforestation & Jobs, Disease & Treatment, GMOs, Habitat Preservation, Organic Farming, Privacy & the Internet, Racing, Recycling, Rights and New Technologies, SUVs, Wildlife Management, and War.

Values Clarification

Values clarification (VC) is a method that deals with the *process* of valuing and challenges students to formulate and test their values against a range of issues. VC is intended to help students communicate their beliefs, feelings, ideas and values, as well as empathize with others. It is a method that assists students in holding and using consistent beliefs and values. There are four general phases in the VC method: (1) the comprehension phase, (2) the relational phase, (3) the valuational phase and (4) the reflective phase. Similar to the first stage of the controversial issues method, the comprehension phase involves clarifying and interpreting the issue. The second phase challenges students to define how, if at all, they relate to the issues. In the valuing stage, students are challenged to make ethical judgments (good or bad, right or wrong, fair or unfair, etc.) on the issue. They are challenged to choose and elaborate preferences. In the reflective stage, students assess potential consequences to and conflicts with their choices. They face the imperatives of their choices. The VC method aims to move students from a process of identifying and prizing to choosing and acting on beliefs and values (Raths, Merrill, & Simon, 1966):

Prizing one's beliefs and behaviors:

1. Prizing and cherishing
2. Publicly affirming, when appropriate

Choosing one's beliefs and behaviors:

3. Choosing from alternatives
4. Choosing after consideration of consequences
5. Choosing freely

Acting on one's beliefs:

6. Acting
7. Acting with a pattern, consistency and characterization

Values clarification in technology studies involves helping students become aware of their beliefs about technology and technological practices they prize and would stand up for (Prizing and Affirming). VC allows students to consider alternative ways of thinking about technology and acting in accordance with values. VC encourages students to weigh the pros and cons and consequences of various technological alternatives and to choose among alternatives (Choosing). Students are encouraged to determine whether their beliefs and positions on various alternatives match their actions, and are helped to bring beliefs and actions in harmony. Finally, students are given real world options to make choices and test their beliefs and assess the consequences of their actions (Acting). Basically, CV helps students deal with moral dilemmas in their lives and works in tandem with the controversial issues method.

A small design project can serve as an example of how the VC method can be used in technology studies. The project provides for a fair amount of choice among materials and one of the choices is the use of southern rain forest wood, such as mahogany or teak. The responsibility is in the teacher's hands to provide a detailed description of rain forest tree harvesting practices and the arguments for and against (see controversial issues method). A brief description of the interdependencies between southern jungles and northern home furnishings would be necessary. At this point, the stage is set for VC. The first step is to prompt the students to name the values they prize and cherish regarding their surroundings, their fashions, and their products. Ask them to write down answers to the following yes-no questions. Do you want to feel exotic? Do exotic clothes or products make you feel exotic? Do you care if your exoticism comes at the expense of the health of your environment? Do you care if your exoticism comes at the expense of the health of an environment in another part of the world? These types of questions help the students to clarify the values they prize and cherish. The second step is to provide alternatives for them to choose among values and the consequences for their choices. Provide a list and description of alternatives to choose from, including rain forest mahogany. For example, a teacher may say the following: If you choose a local wood (e.g., fir) and stain it red, it may look obvious that it is stained. If you choose just one kind of wood your box may be just like many of your peers. If you choose mahogany you may be partially responsible for a homeless parrot family or the destruction of the jungle. The third step is to let the students choose and act on their choice. Ideally, their values will be tested again in a similar situation.

This is a simplified test that pits ecological diversity against fashionable exoticism. You may feel this is a false dichotomy. Or you may go ballistic if they choose to use mahogany, in which case, you probably should not have exotic woods in your workshop. VC means that students are taught a process. There are issues where it may be important for the teacher to take a stance and make choices for the students, or weigh in on influencing their decision one way or the other. Teachers have to make a choice on issues when to enact VC and when to take a stand. If teachers feel that the rain forest can take no more development that is driven by northern demands, they will do well to insist that students rethink their values on exoticism. The harvesting of elephant tusks is another example where demands are inharmoniously interdependent with supplies. In a digital design course, the question of sexism in advertisements may serve as another case for VC. Should students use scantily clad females or males in the ads they are creating? VC invariably brings students to the brink of choice, and asks them to make a choice among values. The premise here is that it is all too easy to be suspended in information and neutrality. "Someone else will make the decision for me" is an expression of an apathetic attitude. When ought the teacher declare her or his values? A delicate balance is recommended. Teachers who moralize too much forfeit influence at times or even create intentional dissent. Teachers who don't care, waffle or fence-sit appear to be apathetic or flighty. Technology studies provide a wealth of issues and opportunities for students to develop the process of VC for future decisions.

Class Discussion

Class discussion is one of the most common teaching methods and one of the most misunderstood. Systematically facilitated, it is also one of the most democratic of methods. Discussions can be facilitated by the teacher or by one of the students. It is an effective democratic method for dealing with a wide range of issues, be they classroom management or controversial issues. Students can prepare for components of the discussion by researching outside class, or arrive fresh to the discussion drawing upon their experiences. Discussions can take the form of responding to an issue, asking students what they think the most important issues to address might be; it could be in response to a demonstration or presentation, an assigned reading or field trip. Braundy (1997, p. 45-50) proposed the following guidelines for discussions and responding to students in general:

Guidelines for Stimulating Discussion

- Ask for more information to help clarify or make the response more specific: "Can you give me an example?" or "Please clarify what you mean by…"
- Restate what you have heard. Also called paraphrasing, this technique lets the participant know that her or his ideas have been heard correctly.
- Use questions to introduce larger issues and develop critical thinking: "Can we take this one step further?" "What solutions do you think might solve this problem?"
- Accept controversial answers to create an atmosphere of open inquiry and debate. Encourage learners to assess and evaluate each other's solutions. Ask the same question of several participants to elicit a range of responses.

- Use open-ended questions (those that can't be easily answered with a simple yes or no) to encourage participants to provide longer, more thoughtful answers. Try not to answer your own questions.
- Have students keep track and provide feedback on the process. Have them look at these factors: Who talks? For how long? How often? Whom do people look at when they talk: individuals, the group, nobody? Who talks after whom, or who interrupts whom?

Guidelines for Assessing Participation

The following list provides a useful framework for teachers to use in assessing participation in class discussions:

- **Initiating:** Proposing tasks or procedures, defining problems, identifying action steps.
- **Eliciting:** Requesting information, inviting reactions, and soliciting ideas.
- **Informing:** Offering information, expressing reactions, and stating facts.
- **Blocking:** Introducing irrelevancies, changing the subject, questioning others' competence.
- **Entrenching:** Expressing cynicism, posing distractions, digging in.
- **Clarifying:** Clearing up confusions, restating others' contributions, and suggesting alternative ways of seeing problems or issues.
- **Clouding:** Creating confusion, claiming that words can't "really" be defined, remaining willfully puzzled, quibbling over semantic distinctions, obscuring issues.
- **Summarizing:** Pulling together related ideas, offering conclusions, stating implications of others' contributions.
- **Interpreting:** Calling attention to individual actions and what they mean.
- **Consensus proposing:** Asking whether the group is nearing a decision, suggesting a conclusion for group agreement.
- **Consensus resisting:** Persisting in a topic or argument after others have decided or lost interest, going back over old ground, finding endless details that need attention.
- **Harmonizing:** Trying to reconcile disagreements, joking at the right time to reduce tensions, encouraging inactive members.
- **Disrupting:** Interfering with the work of the group, trying to increase tensions, making jokes as veiled insults or threats.

- **Evaluating:** Asking whether the group is satisfied with the proceedings or topic, pointing out implicit or explicit standards the group is using, suggesting alternative tasks and practices.

Cooperative Learning or Dyads

Cooperative learning refers to any pairing of between two and six students for learning (Braundy 1997). Cooperative environments generally foster greater learning and retention than larger modes of instruction (e.g., lectures). Cooperative groups can be formal study groups, informal discussion groups or task-oriented groups. Cooperation, creativity, responsibility, constructive feedback, conflict resolution skills, and problem-solving skills are typically developed and necessary in small group environments. Students get to informally address their assignments. The teacher's task is to foster a positive emotional environment where group members experience a sense of responsibility and interdependence.

Cooperative learning provides an environment where those who may be reluctant to present their ideas in a large group may find some comfort and confidence. Dyads (two), triads (three), or small group discussions enable students to cooperate in activities and projects. In the world of business, design, and production, small teams are formed and reassembled to form a larger, cohesive whole in the design and production of products. Hence, cooperative learning has very important implications for technology studies. Braundy (1997, p. 49-50) offers the following guidelines for cooperative learning:

- Divide the students into subgroups of four to six. Make sure the students are seated next to each other to facilitate interaction.
- Clearly state the problem or issue that they are supposed to address. Write it on the board, provide handouts, refer to your Web site or use an overhead projector to ensure that the students understand what is to be addressed.
- Have the group members select a recorder and spokesperson to keep track of the progress of the group.
- Briefly discuss approaches to the issue and deal with any questions.
- Have participants deal with the issue for the designated period of time while you circulate from group to group assisting as necessary.
- For assessment, it is useful for the groups set to work on a particular project, design, or research project, to have an opportunity to evaluate the group effectiveness.
- For an icebreaker, students give the students a question to resolve, such as this: "Who are the key professionals, besides the architect, involved in designing,

financing and constructing a building?" Tell each group to generate as many responses as possible in three to four minutes. Ask a designate spokesperson from each group to report

Debriefing

Debriefing and feedback facilitate reflection and make experiences worthwhile. Debriefing is a method used to provide an environment or platform for the expression of feelings and transfer of knowledge following an experience. Debriefing may come at the hands of a traumatic event or may be used more generally following an intentionally educational experience. Debriefing relies on the skills of the facilitator to reframe an experience or event in order to appropriately channel emotions and knowledge toward understanding and transformation. For some experiences, this could be as simple as bringing the group of students together and asking: "How did it go?" or "What are the important things we can draw from this experience?" Other experiences will require a more formal approach that is structured within a framework somewhat similar to the controversial issues framework. If an experience is important enough to undergo in technology studies, it ought to involve a degree of debriefing.

Debriefing may involve feedback to the students or among the students, but this is not the intent. The intent is to allow the students to "thaw" and to judge their experience and progress toward change or transformation. The intent is to help them come to terms with their experience. This process involves a cognizance of cycle that students may have to be guided to completely debrief (Table 4). Some students will have no intention of debriefing and will have to be coaxed, but not coerced, into the process. Once inspired to debrief, teachers can begin to help their students contemplate what happened—what went right or wrong. Through this early stage of debriefing, students may show a determination to change, improve their strategies, and make plans. Over time, many will maintain their behavioral commitments. Others will relapse and this is perfectly normal. Teachers should not be overly critical of relapses in behavior. Once the experience is completely integrated, the students will exit this cycle and get on with the next. The debriefing cycle is a mini-cycle in the larger cycle of experience explained in Chapter VI and in the learning style section at the end of this chapter. A range of other teaching methods, such as creative problem-solving, projects, modules and units will be explained in Chapters V and IX.

Table 4. Debriefing cycle

Precontemplation	No intention of debriefing
Contemplation	Considering the experience
Determination	Decision to change and strategizing
Action	Commitments and plans made
Maintenance	Maintaining commitments
Relapse	Normal process of backsliding and recycling
Exit	Experience fully integrated

Research Methods

Models of active learning require that students spend a fair amount of time constructing knowledge. Most often, teachers provide pre-established knowledge for their students to analyze and contemplate. At times, teachers design the route and passageways for students to construct and discover new knowledge *via* a discovery method. Here, the teacher is well aware of the type of knowledge to be constructed. At other times, teachers equip their students with a research method to challenge them to construct new meanings and knowledge. In schools, the research methods are simplified, allowing the students to access the methods at their own levels.

Research Methods

1. **Content analysis:** A systematic method in the social sciences by which contents of spoken or written text are counted. This involves counting the number of times particular words, or phrases, are used, within selected passages (speeches, news stories, etc.). Conceptual and operational codes, like conservative or radical, and economic or cultural help to give latent meaning to the analysis of content.
2. **Critical incident:** A method where students are challenged to identify critical incidents in their lives to examine and elaborate on (Chapter XI).
3. **Design:** Students are challenged to generate tangible solutions to problems, through fairly strict rules guiding aesthetics, function and form (Chapter V).
4. **Disclosive analysis:** Disclosive analysis refers to a group of methods that are used to derive meaning from the artificial and natural worlds. Common disclosive methods include basic causes, ecological footprints, laws of media, life cycle assessment, quotidian deconstruction, resource streams, reverse engineering, sociologics, systems analysis, technology assessment, and forecasting (Chapter V).

5. **Discourse analysis:** A social science and literary method for analyzing meaning in the images and text of communication. In most cases, this method is used to link everyday discourse with power structures or propaganda.
6. **Discursive analysis:** A philosophical method that draws on techniques such as logic and dialectics to help students analyze claims, grounds, warrants, and conclusions in arguments and discourse. Students are given problems and proposed solutions to analyze and determine whether means are commensurate with ends, or whether ends justify the means.
7. **Ethnography:** An anthropological method of observation. Students are challenged to observe and record the actions and culture of subgroups within their own communities.
8. **Forecasting:** Students use methods of Delphi survey, extrapolation, trend analysis, or scenario to project into the future and study the future as a continuum of the past and present (Chapter V).
9. **Genetic method:** A method that focuses on the manner or process by which anything comes into experienced existence. As a teaching method, it is also anthropological in the sense that students trace the "development" of cultures, including their own, through evolutionary stages of growth. Often called the cultural epoch approach associated with recapitulation theory (Related to genetic epistemology of Piaget and Vygotsky).
10. **Hermeneutics:** The theory and practice of interpretation. This method is common to theological scholars who interpret religious texts. The text must be given space to speak for itself, literally, without editorial license.
11. **Historical method:** Students document (serialize events, organize thematically) continuity and changes over time and analyze and judge the nature of these continuities and changes.
12. **Jurisprudence:** A general method where students follow the legal arguments of a case or establish a court to hear trials and cases. The use of legal techniques to make or break cases that involve issues close to the students such as graffiti laws, minimum wage or war.
13. **Narrative:** A method for making sense of experiences by placing feelings, observations and thoughts into a story form. Narrative helps students connects a wide range of knowledge by challenging them to construct a coherent story. Narrative typically accompanies other methods, such as the historical methods.
14. **Phenomenology:** A method for getting to essences of feelings and experiences. The key is to analyze the lifeworld and nature of experience in pre-reflective ways, or without guiding concepts and theories.
15. **Problem finding and solving:** Students are challenged to identify problems or are presented with perplexing, difficult problem, to think about, troubleshoot,

and try to resolve. Typically, problem-solving is done with an empirical procedure (technological method) or scientific method (Chapter V).

16. **Quotidian deconstruction:** A form of disclosive analysis that focuses on the feelings that people derive from their existence of "being human in a more than human world" (Feng, 2003). Students focus on their everyday life and use phenomenology to help them disclose their desires and feelings about the nature of nature and technology (Chapter V).
17. **Scientific method:** A general method for logically testing hypotheses, proving theories or constructing generalizations and models. Deductive method begins with a hypothesis to be proved or tested (physical sciences) and proceeds within the constraints of an experiment Inductive method begins with observations and proceeds through methodical examinations of evidence and subsequent observations (biological and earth sciences) (Chapters II, V).
18. **Survey:** Students prepare a questionnaire to collect information on some topic of interest and eventually analyze the information.
19. **Systems analysis:** A method of for analyzing human-machine and machine-machine interactions by determining the inputs and outputs of a given system. This is an effective method of disclosive analysis for demystifying the operations and inner workings of natural, social, or technological systems (Chapter V).
20. **Task analysis:** Techniques used to identify the details of specified tasks, including the required dispositions, knowledge, and skills required for successful task performance. Worker-oriented, job-oriented, cognitive, and emotional task analysis help students engage with career-related knowledge (Chapter VIII).
21. **Technological method:** See design, problem-solving and scientific methods (Chapters II, VIII).
22. **Technology assessment:** A specific form of disclosive analysis used or assessing the cultural, ecological and social consequences (collateral or deferred) of technological events, practices, trends and values (Chapter V).

Each teaching and research method, model and family is essential to the practice of technology studies. Teachers have their strengths and weaknesses, and adopt particular models to complement strengths and contradict weaknesses. You will feel more comfortable working within a particular family of methods. For example, you may feel secure with the control that the behavioral modification family offers. You may feel uncomfortable with the messiness and lack of control of the information processing family. You may feel at home with the personal family and its methods and alienated by behavioral modification. Nevertheless, you will have to come to terms with why you prefer some to others and develop proficiencies and facilities for teaching within each of the families. You will have to come to terms with your own style.

Teaching Styles

Teaching style refers to the manner in which a teacher manages instruction and the classroom environment. There are three major teaching styles (permissive, authoritarian, and democratic) that are prevalent in classrooms. Most of us have a teaching style that is dominant but display characteristics that include some aspects of each of the other styles (e.g., Joyce & Weil, 1980; Riessman, 1967; Rubin, 1985). The teaching style that identifies your personality in the classroom controls most aspects of your instruction, classroom management strategies, and techniques. Your teaching style determines how you implement classroom management tasks. Permissive teachers establish few rules and tend to be inconsistent in enforcing rules or applying consequences for misbehavior. Authoritarian teachers establish the classroom rules, learning is teacher centered, the student's role is to comply with the rules and complete all work satisfactorily. Democratic teachers establish a classroom environment that includes input on nearly all issues of management, voting privileges for students, and generally positive reactions to student desires and needs. Authoritarian and democratic teaching styles tend to be most effective because disruptions in the classroom are kept to a minimum. Teachers who exhibit a permissive teaching style sacrifice an orderly classroom by trying to allow the students to police themselves. Permissive teachers are generally hands-off, encouraging their students to develop independence and individual responsibility. Many new teachers enter the teaching profession because they like children and teens and enjoy being around them. Beginning teachers tend to be permissive in their dealings with students. Students quickly pick up on these tendencies to overlook minor infractions. Classroom control typically suffers as a result. It is recommended that new teachers develop a teaching style that leans toward authoritarian or democratic style personality types. In Chapter XI, we will address classroom management as it relates directly to teaching styles.

Teaching styles do not develop naturally and without practice or experimentation. It takes time before a teacher establishes a style that accommodates particular teaching methods and families. Permissive teachers tend toward the personal and social families of instruction and emphasize discussion and Socratic methods. Authoritarian teachers prefer direct instruction and information processing and behavioral modification families. Democratic teachers typically adopt managerial methods and find the social interaction family of methods to be most conducive to their style. It is extremely important that teachers clearly understand their style and consistently use one or two styles. Each teaching style and the degree to which the teachers express it has implications for the styles that the students bring to the classroom.

Personality Types

Your preference for certain methods, families, or teaching styles will be directly related to your personality type. We develop a fairly distinct, recognizable personality type through the conditions under which we were raised and the events that we have endured. Our personality type acts as a filter that sets the tenor of our lives. Rather than a projection of our true selves, personality types serve to protect a specific aspect of our inner selves. Personality types help us cope with the world, and color the way we see people and make decisions. There are literally dozens of tests and inventories for determining personality types in individuals. Psychological therapists, beginning with the work of Carl Jung, use personality types to help people adjust to social conditions or overcome their personal issues. Career counselors and educators use personality type inventories to guide students toward careers and interests that are congruent with their personalities. Teacher educators use these inventories to help teachers realize how their personality types shape their classroom practices. For example, teachers with a perfectionist personality type will tend to prefer methods that allow for detailed mastery and will organize their labs and workshops in very orderly ways.

Jung introduced the notion of introverted and extraverted personalities. Introverts find energy and solace in the inner world of abstractions, concepts, and ideas. They can be sociable but need quiet time to recharge their energy. Introverts want to understand the big picture and how the world works. Introverts learn most through concentration and reflection. Extraverts find energy in doing things and interacting with people. They are comfortable with addressing facets of a problem rather then the whole problem. Extraverts learn most through interaction and in-the-moment discussion. Most expanded systems of personality types are based on variations of these two basic types.

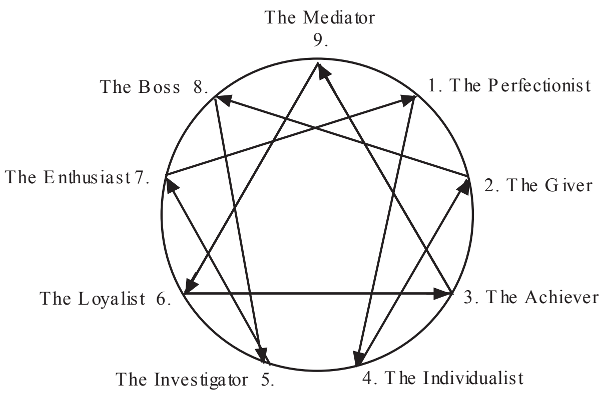
The Enneagram is one system of personality types that was popularized by Helen Palmer in the 1970s (Webb, 1996). The Enneagram has nine personality types and depicts their relationships as well as the direction that particular personality types will tend in times of security and stress (Figure 1). Type ones (perfectionist) are independent, responsible, hard-working people with high standards. They can also appear to be irritable, intense, judgmental, self-righteous, and compulsive. Type twos (giver) are independent and capable, and prefer giving to receiving. They can appear naïve, proud, and manipulative. Type threes (performer) are ambitious, high-achievers, good motivators and work hard in pursuit of their goals. The can appear cold and manipulative and can disregard people in pursuit of their goals. Type fours (romantic) are dramatic, intense, and attracted to extremes. They can appear flamboyant, elitist, and superior. Type fives (observer) are analytic, reflective, and observant. The can appear withdrawn, distant, intellectual, objective, quiet, and unemotional. Type sixes (questioner) are loyal, dependent, cautious, and imaginative.

They distrust authority and can appear calm, cautious, and guarded. Type sevens (epicure) are cheerful, energetic, charming, and elusive. They can appear busy, superficial, and self-centered. Type eights (boss) are assertive, energetic, intense, rebellious, and direct. They can appear bossy and dogmatic, and see the world in black and white. Type nines (mediator) are accommodating, talkative, uncompetitive, tolerant, warm, and good listeners. They can appear laid back, mellow and predictable. There is not a "best" type. All personality types have their advantages and disadvantages, light sides and dark sides. One of these personality types may have immediately resonated with you as they were described.

The Enneagram divides personality types into three sections of the circle. Each section corresponds with ways in which we experience the world: sensing, feeling, and thinking. The three personality types at the top of the circle, boss, mediator and perfectionist, favor instinctual intelligence and speak of making decisions based on gut feelings. These types tend to be in the world through action. They primarily perceive the world through doing. The three types in the lower left section of the circle, epicure, questioner and observer, favor thought, imagination, and analysis. They tend to respond to the world through their thoughts. The types in the lower right section, giver, performer and romantic, operate in the world through relationships and are concerned with how they are seen by and relate to others. They tend to respond to the world through their feelings.

This section was not to fully explain the Enneagram or personality types. The objective was to provide an idea of how your personality type will influence your choices of teaching methods and development of a teaching style. "Know thyself" is the best advice here. But as teachers, we cannot justify our selections of teaching methods and styles by our personality types. Would we allow our students to justify their behavior by their personality types? We all have a comfort zone and

Figure 1. Enneagram of Personality Types



our challenge is to encourage our students to move from their comfort zones. We cannot address all students, their personalities, or their learning styles by a single teaching model, family method, or style.

Learning Styles

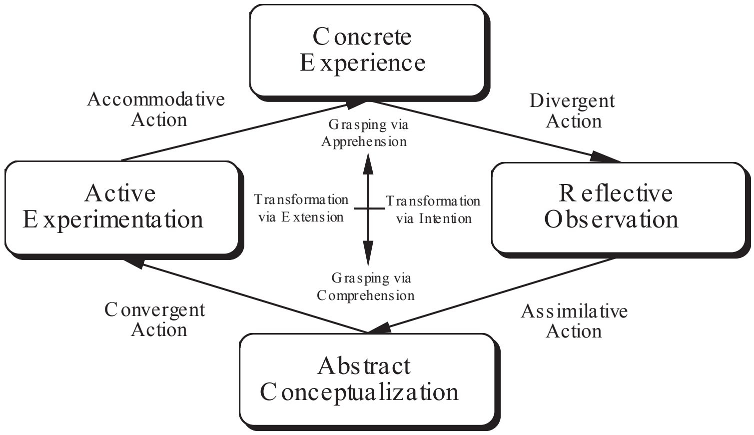
If we get too comfortable, we stop growing. Students can put pressure on us to work within their comfort zone. Let's be kind about that. Kind enough to let them learn to be uncomfortable. (Herbert Thelen, quoted in Joyce & Weil, 1996, p. 385)

Just as teachers will develop preferences for particular methods, students develop preferences for particular way of learning. We teachers, and our students, probably have preferred ways of perceiving and processing new information. These preferred ways are called learning styles. Typically, our students and we like to know why we are learning something, like to have time to practice, and time to integrate what we have learned into our lives. While schools may excel in delivering facts and overlook the importance of the previous three stages, we cannot dismiss the fact that individuals have preferred ways of learning. Individuals have preferred ways of learning throughout the different stages of learning.

Learning styles address the ways we perceive and process. Perceiving relates to the way we notice the world and the way we see reality. Processing relates to the way we internalize an experience and make it our own. Some people prefer to perceive the world through concrete experience. These people perceive by sensing and feeling, and prefer to use intuition to solve the problems of a given task. They function well in unstructured situations. Other people prefer abstract conceptualization. They like to think things through, analyze, and intellectualize. They function well in structured situations. Some people prefer to process new information by active experimentation. They like to roll up their sleeve and immerse themselves in the task. They look for practical ways of applying what they learn. They embrace risk-taking and are results oriented. Other people process through reflective observation. They like to watch and ponder the situation. They likely see tasks from several points of view. They value patience and judgment. Concrete experience, abstract conceptualization, active experimentation, and reflective observation are four general learning styles (Figure 2).

There are numerous theories of learning styles and categories of learning styles associated with the theories. For example, some educators use Howard Gardner's theory of multiple intelligences and derive nine learning styles from his nine intelligences. Others use Rita Dunn and Kenneth Dunn's (1978) learning styles inventory, which focuses on the environmental, emotional, sociological, physiological, and psychological aspects of learning. Their learning styles are derived from com-

Figure 2. General Learning Styles



binations of these aspects. Bernice McCarthy's learning style theory is based on right-brain, left-brain neurological science and David Kolb's learning cycle work. Generally, the following nine learning styles, in pairs, are considered to be the most common. Of course, most of us function by accommodating combinations of a range of learning styles.

The most common test of learning style is the 126 item Myers-Briggs Type Indicator (MBTI), Form G. The MBTI provides data on four sets of preferences. These preferences result in 16 learning styles, resulting from combinations of introversion vs. extraversion, thinking vs. feeling, sensing vs. intuition, and judging vs. perceptive.

Thinking students choose to decide things impersonally on analysis, logic, and principle. Thinking students value fairness. They place great weight on objective criteria in decision making and judge situations on logic and reason. Data, on *Star Trek*, had an extreme preference for thinking. Feeling students value harmony. They focus on emotions and needs as they make decisions or arrive at judgments. They tend to be good at conversation, persuasion, and facilitating differences among group members. The character played by Whoopi Goldberg on *Star Trek* demonstrated an extreme preference for feeling. Some students choose to rely on their five senses and prefer taking in information through a "sixth" sense. Sensing students are detail oriented and want facts and explanations. Intuitive students, on the other hand, seek out patterns and relationships among pieces of information. They trust hunches and their intuition and look for the "big picture." Some of students prefer to postpone action and seek more information. Others like to make quick decisions, to "get on with the show." Judging students are decisive, plan out their decision and are self-regimented. They focus on completing the task, only want to know the essentials, and speak or act quickly, often too quickly. Deadlines and clearly defined roles are

Table 5. Learning styles

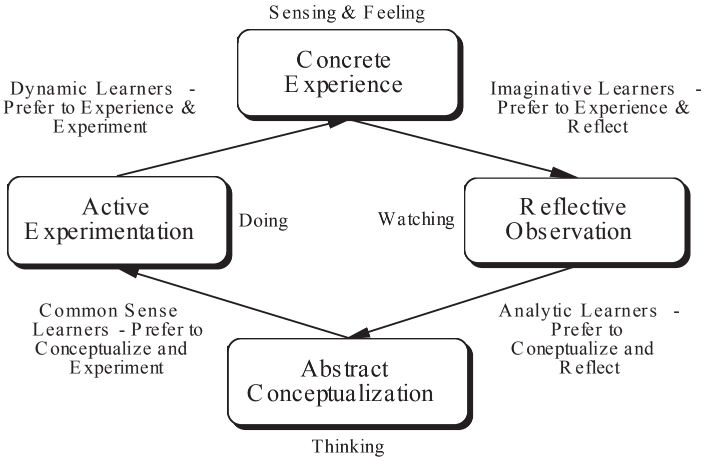
Global or feeling: Prefer to have big pictures of tasks presented first. Learn most effectively when a meaningful context is provided.
Analytic or thinking: Prefer to have small steps build to whole. Learn most effectively when pieces are provided first.
Verbal: Rely on words and labels. Prefer to have definitions over images.
Imaginal or Intuitive: Prefer to have images (concrete or abstract), metaphors, symbols, and diagrams. Difficult concepts are best explained through images.
Concrete or Sensing: Prefer concrete examples, followed by concepts or principles.
Abstract or intuitive: Prefer concepts of principles prior to concrete examples.
Haptic, trial and feedback, or judging: Prefer doing tasks and hands-on applications followed by feedback. Prefer to make errors and build on trials and errors.
Reflective or perceptive: Prefer to think through and reflect on tasks prior to trials. More dependent on time to respond than on external feedback.
Relational: Prefer to link new material to what is already known, or unfamiliar tasks to familiar tasks. These students need time to discuss what is being learned prior to executing the tasks.

extremely important. They prefer to "just do it!" Perceptive students are curious, flexible, and relatively spontaneous. They start many tasks, have to know the details about each task and often find it hard to complete a task. Deadlines are meant to be moved. Their motto is "but wait a minute!"

Research suggests that 90% of girls and women in technology and 60% of boys and men are relational learners (Braundy, 1997). They learn best when relations are drawn between different technologies (e.g., fastening seams on cloth when sewing compared to fastening seams on metal when soldering; fish scales compared to files), and when tasks are related to their lives. For this second point, instructors have to reiterate the relevance of what is being learned by relating it to the students' school life, potential work life, or everyday home life. Personal stories from the instructor's life work well here. These learners prefer to link new material to what is already known, or unfamiliar tasks to familiar tasks. These students need time to discuss what is being learned prior to executing the tasks.

Most, if not all, of the activities and projects we use in technology studies ought to complete a cycle of learning styles. We ought to provide time for and concrete experience (activities, projects) and reflective observation (demonstrations, examples). Students need time for abstract conceptualization (discussions, questions concerning why and what) and time for active experimentation.

Figure 3. McCarthy's 4Mat Learning Cycle



Bernice McCarthy (1987) expanded on Kolb's learning cycle, and defined her four general learning styles as imaginative, analytic, commons sense, and dynamic (Figure 3). Imaginative learners prefer to experience and reflect. Analytic learners prefer to conceptualize and reflect. Commons sense learners prefer to experiment and conceptualize. And dynamic learners prefer to experiment and experience. McCarthy stresses that we should accommodate all four of these learners in our activities or lessons.

Most learning styles, including McCarthy's, are based of perceptual modality preferences. Perceptual modality refers to the way we perceive or take in the world. The notion of sense modalities is based on the perceptual learning styles theory of Cherry (1981) and Gilley (1975). Perceptual learning styles refer to the means by which learners extract information from their surroundings through the senses. Each individual has a preferred sense for accessing knowledge—they use different "pathways" specific to them. Initially, knowledge is stored in short-term memory. Repeated exposure, experience, and application promote retention in long-term memory. Perceptual learning styles refer to the pathways we use to access and reinforce knowledge. According to this theory, there are seven pathways or learning styles at work in the average classroom:

1. **Print:** Refers to seeing printed or written words.
2. **Aural:** Refers to listening.
3. **Interactive:** Refers to verbalization.
4. **Visual:** Refers to seeing visual depictions such as pictures, graphs.

5. **Haptic:** Refers to the sense of touch or grasp.
6. **Kinesthetic:** Refers to whole body movement.
7. **Olfactory:** Refers to sense of smell and taste.

For example, dynamic and common sense learners tend to be haptic, kinesthetic, or enactive. They prefer to learn by physical contact and the "mind's hand." Imaginative learners tend to be visual or iconic. They prefer to learn by figural and spatial thinking or the "mind's eye." Analytic learners tend to be auditory or symbolic. They learn through verbal thinking or the "mind's ear." In chapter six, we will explain the role of perceptual modalities in various learning theories.

The fact that people learn and process information differently is *not* under contention. Nonetheless, the degree of differences between people and questions of how and why people differ are under contention. Research into the sources of learning styles often reflects the tired arguments between nature and nurture in explanations of intelligence. Neuroscientists attempt to explain the differences through biological and physiological descriptions. Social scientists attempt to explain learning styles by referring to socioeconomic conditions, familial tutelage or class, gender, race and sexuality.

Brain lateralization, or the notion that the left side and right side of the brain are differentiated by function, has had the greatest influence on learning style theorists. This notion originated in the "split-brain" research on patients with epilepsy during the 1960s. The neurophysiologists who did the research concluded that the brain was divided into two "spheres of consciousness." They theorized that the left side was the site of speech and rational thought while the right side was the site of intuition and spatial abilities. From this, an entire discourse on brain lateralization was founded. According to the myth, left hemisphere is logical, verbal, and dominant. The right hemisphere is imaginative, emotional, spatially aware, and suppressed. Hundreds of articles, books, and Web sites promise techniques to liberate the right side of the brain (e.g., *Drawing on the Right Side of the Brain*). In the urban legend of cerebral lateralization, the brain neatly divides its labor between left and right functions such as linear and holistic processing, sequential and random processing, symbolic and concrete processing, logical and intuitive processing, verbal and nonverbal processing, and reality-based and fantasy-oriented processing. Such simplicity is not the case.

Most neuroscientsts claim that the discourse is mythical, noting that research on brain lateralization is complex, contradictory, and inconclusive. First, any lateralization that may exist in the brain is based on a difference of processing style, not function. In other words, intellectual tasks are shared across hemispheres, and each side contributes in a complementary, not exclusive, way. Experiments involving navons, or images that have a larger coherence but are made of smaller parts, are at the base of the controversies. Subjects with their brains wired to scanners are given a series of navons, such as a large letter S, which is made up of small letter Fs. Their reactions in the left and right hemispheres depended on whether the subjects concentrated on the whole (the S) or the parts (the Fs). However, activity on each side on the brain was reversed when the subjects were given 3D object navons, such as an anchor made up of little boats. These types of contradictory findings have left most neuroscientists to stick to their original conclusions: Brains have evolved to be balanced across hemispheres, drawing on the left, and rights sides to process the same tasks.

Projection and Reflective Practice

In chapter one, we acknowledged that a basic cycle of communication was at the base of instruction and instructional planning. We also asserted that the most common instructional strategy for technology teachers was demonstrations. In this chapter, we argued that teachers ought to think systemically about instruction. Instructional strategies are a component of a larger instructional system. We noted that our instructional strategies, or teaching methods, must be sensitive to other components in the system and respond to other systems, such as the learning system. Our personality type inherently influences our preferences for particular teaching models, families, methods and styles. However, this does not excuse us from attending to our students' preferences. We must develop a toolbox with a range of teaching methods so that we can anticipate and respond to our students' learning styles and perceptual modalities. The learning style cycle, developed by McCarthy, helps us to think systemically about instruction and learning.

Of course, learning styles are only one characteristic of students. Students arrive with basic needs (food, shelter, clothing, emotional love) that differ. They have different capabilities, interests, personalities and racial or gender characteristics. Students mature at different rates. Students without much discipline or stability in their home life need discipline and stability in their school life and teaching methods. Look at the grid or table of specifications below. Across the top are teaching methods and on the left are various ways by which students are differentiated. The purpose of this grid is to demonstrate the challenge of finding one method that is adequate for all students. Picture the addition methods to meet content objectives and various societal expectations! Obviously, there is no "one size fits all," generic method. Nor is there a scientific way of merely correlating student characteristics with methods, as the grid may suggest (Table 6).

In the next chapter, we address the issues and challenges of teaching creativity, ingenuity, design, and problem solving. Specific teaching methods, such as design briefs, respond quite effectively to teaching creativity and ingenuity. We will pro-

Table 6. Student characteristics by method

Nature of the students:	Teaching method or instructional strategy										
	Lecture	Discussion	Demonstration	Hand-outs	Controversial Issues	Values Clarification	Role Playing	Problem-solving	Design Brief	Module	Project/ Report
Developmental tasks and maturity											
Learning styles											
Diversity of interests											
Diversity of capabilities											
Experiential background/ entry characteristics											
Special needs and abilities											
Class, gender, & racial differences											

vide details for developing design briefs and other methods specific to design and problem-solving.

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Chapter V

Creativity and Ingenuity, Design, and Problem-Solving

Introduction

One of the most used and abused approaches to technology studies in the schools is creative design and technological problem-solving. Current research suggests that it is not clear what students learn, if anything, in many creative design and technological problem-solving activities. Recalling the previous chapters, it is not enough to merely involve students in activities and problems. Emotions, knowledge, and skills must be articulated, organized, and demonstrated. Inferences from mistakes and successes must be drawn. Procedures must be practiced. One of the reasons that creative design and technological problem-solving activities are often without adequate results is that technology teachers tend to take creativity, design and problem-solving for granted. We assume that creativity, design, and problem-solving are automatic components of what we practice in technology studies. However, little is automatic in education. There is more to design and problem-solving than learning methods and resolving technical problems. In this chapter, current research is brought to bear on creative design, ingenuity, and technological problem-solving.

In technology studies, one of our missions is to demystify the processes and products of design and technology. It is not enough to merely teach students to express their creativity, design or solve problems. We use the processes of creative design and problem-solving to disclose self-knowledge and feelings as well as the cultural and material conditions of subsistence, work, and home life. It is relatively easy to say this is the case. What remains is for us to describe *how* technology teachers can derive knowledge and feelings from technologies. *How does doing lead to knowing?* This chapter explains eleven methods of disclosive analysis for teachers to use with their students to demystify the processes and products of design and technology. The chapter concludes with an explanation of design briefs, an essential tool for engaging students in design and problem-solving.

Creativity, Imagination, and Ingenuity

Can creativity and ingenuity be taught? Can the imagination be nourished? If so, how? What is creativity? A typical library catalogue search for the word "creativity" produces over 1,000 titles, and searches of commercial book dealers on the Internet produces 680,000 titles. The entry of creativity as a keyword in the ERIC (Educational Resource Information Center) database produced 25,348 journal articles in 2001. When one enters the phrase "technology and creativity" into the Google Web search engine, 787,000 sites are listed. An ERIC search using the same phrase produces 1,614 possible journal articles (Lamonde, 2001, p. 56-58). Coming to terms with creativity is overwhelming. On one hand, the volume of references to creativity reveals its significance. On the other hand, due to this popularity, it is difficult to take it seriously.

Early inquiries into creativity isolated four stages in the creative process: preparation, incubation, illumination, and verification (Wallis, 1926). Not coincidentally, the four stages reflected the stages of problem-solving isolated by Dewey in 1916. Many a teacher attempted to provoke creative thought in their students by walking them through these four stages. Other teachers emphasized Guilford's (1950, 1967) criteria for creative products: ideational fluency, flexibility, elaboration, and originality. Definitions of creativity referred to both the process of reaching a novel achievement and the novel achievement itself. Researchers generally defined creativity as the "recombination of known elements into something new" (Ciardi, 1956) or more currently as "bringing something into being that is original (new, unusual, novel, unexpected) and also valuable (useful, good, adaptive, appropriate" (Ochse, 1990, p. 2). Rossman''s (1964) classic study, *Industrial Creativity*, identified three characteristics common to inventors: originality, perseverance and imagination. After studying the work of 864 successful (male) inventors, he concluded that "inventing is a learned behavior and there is no evidence that it is intrinsic."

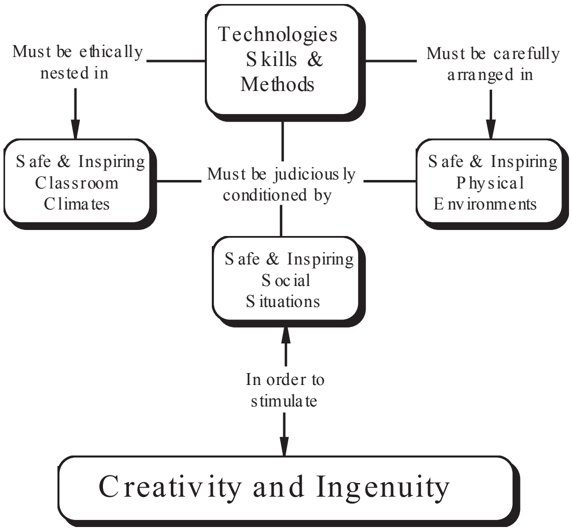
Of course, we want students to reach for novel achievements. Of course, we want unique expressions. Teachers want students to be novel within their world of norms and conformity, to think outside the box. But how novel is novelty if everyone is novel? In order to avoid the pitfalls of defining a creative process or identifying criteria to judge creative products, we will start with current dispositions toward creativity.

According to Howard Gardner (1983, 1993), each and every human has the capacity to be creative in one or a number of eight areas that correspond with theories of multiple intelligences. In Chapter II, we identified these capacities as: Bodily-kinesthetic, Existential, Interpersonal, Intrapersonal, Musical, Logical-mathematical, Linguistic, Naturalist, and Spatial. Creativity in technology or ingenuity directly involves bodily-kinesthetic, logical-mathematical, and spatial capacities. However, ingenuity indirectly draws on the other capacities. In fact, ingenuity is typically defined by uniqueness inspired through the existential, inter- and intrapersonal, musical, linguistic and naturalist capacities. In other words, ingenuity requires that we bring capacities to bear on design and technology that are not normally associated with design and technology. Ingenuity requires a strange brew of capacities; it requires mobility from capacity to capacity. This is the lesson for teachers of creativity. If we want to teach creativity, we cannot limit our curriculum to a few capacities. The operative word is mobility.

Like intelligence, creativity and ingenuity result from a dynamic of biological and cultural (or environmental) forces and functions. Given the cultural sources of creativity, theorists, such as David Perkins (1984, 1986) assert that we can teach students to be creative in any and all areas of their life. It is through culture, and especially *through* material culture, that creativity and ingenuity are developed. Our theory of practice, explained in Chapter VI, grounds the development of creativity and ingenuity, and ultimately design. Creative impulses toward design are inspired through the manipulation of images, information, instruments, materials, tools machines, and products of all sorts. Technologies in general and manipulatives in education specifically, are *not* merely media for the expression of creativity. In our theory of practice, creativity and ingenuity are stimulated through skills and the manipulation of technologies. Of course, we creatively approach and design the technologies we use. But the issue is one of priority. In our theory of practice, the priority is from manipulatives and skills to creativity and ingenuity. Manipulative skills do not dominate creativity, knowledge, or feelings; cognition, emotions, and skills are integral parts of the subject of technology studies.

Like cognition, creativity is neither fully individual nor fully social. Creativity, like cognition, is distributed among information, people, and things. Remove the information, objects and social group and what is left is a partially creative person, an incomplete individual. This of course, is counter to romantic individualism and psychoanalytic theories suggesting that the social group crushes the individuality and creativity of its members. Materials and technologies are *not* merely instrument to creativity and ingenuity; technologies are *not* merely resources. Technology is *not* a mere medium for the expression of creativity. Rather, technologies are integral to creative acts. In an exhaustive analysis of the theoretical underpinnings of creativity, Lamonde (2001) concluded that the imagination and creativity are dependent

Figure 1. Instructional design for Creativity and Ingenuity



on symbolic thought (e.g., language) and media. We learn to be creative, she concluded, by learning how to communicate with people and how to manipulate things. Hence, we cannot merely analyze what goes on in individual, "creative" minds to determine what creativity is or how to teach creativity. To understand creativity we must study environments, events, processes, and situations. To teach creativity and ingenuity, we must create inspiring and stimulating conditions, environments, processes, and situations (Figure 1). Creativity and ingenuity can be intentionally inspired and stimulated, or designed—If we intentionally situate creative people in creative places.

Through certain techniques of synectics, creativity is entered into the solution of problems. Five extremely helpful synectic techniques for individual/group creativity are:

1. **Deferment:** Look first for viewpoints rather that solutions.
2. **Autonomy of the object:** Let the problem take on a life of its own.
3. **Use of the commonplace:** Take advantage of the familiar as a springboard to the strange.
4. **Involvement/detachment:** Alternate between entering into the particulars of the problem and standing back from them in order to see them as instances of a universal.
5. **Use of metaphor:** Let apparently irrelevant, accidental things suggest analogies which are sources of new viewpoints (Lincoln, 1962, p. 274).

Synectics, or operational creativity, is a theory of collective creativity especially attuned to education. Synectics rejects the notion that creativity is simply individual, accidental, or serendipitous. The theory holds that creativity and ingenuity can be methodically and systematically inspired.

Design

"There's enormous opportunity in the concept of design to bridge from talking about concrete things like pencils and paper clips to more abstract things like processes: shopping in the supermarket, for instance, or the algorithm for long division, or computer programs" (Perkins, 1986, p. 14). As mentioned in the previous section, creativity can be intentionally stimulated and inspired, or designed. Creativity can be taught or designed, and the corollary is also true: creativity is the process of design. To say that creativity can be taught is to merely say that design can be taught. However, it is insufficient to simply teach design, to teach students to design things, and call it creativity. It is necessary to think in designerly ways and to see the world through what David Perkins (1986, p. 35) calls "design-colored glasses." Design is not only about changing the world. Design is about understanding the world as well.

Creativity involves the creation of products, whether material or intangible, concrete or abstract. Each of these products is a design. Design can be simply defined as "a structure adapted to a particular purpose" (Perkins, 1986, p. 2). Hence, structures adapted to particular purposes can be arguments, books, cars, genetic maps, houses, the internet, numbers, or a speech. These are deliberate designs. Some designs of nature are also suited to particular purposes through evolution, such as the wings on a bee or bird, and can be considered to be natural designs; they came into being through natural processes and selection. Other senses of design, such as a pattern that serves no particular purpose (crystal lattices, ripples on sand dunes, solar system) are treated as nondesigns. They are regular patterns of nature that serve no particular purpose. Spiritual or theological analysts may attribute natural designs and nondesigns to divine intervention and design. Theoretically then, it is helpful to distinguish deliberate designs from natural designs from nondesigns (Perkins, 1984, 1996).

Creativity is design, and we can also think of knowledge as design. Thinking of knowledge as design allows us to dispense with the notion that knowledge is information, or an accumulated database that can be applied when the circumstance arises. Here, knowledge is passive and in storage for potential uses. Knowledge as design conveys a more dynamic view of knowledge, as generative rather than applicative. Knowledge generates action, and of course, action or experience generates knowledge. Knowledge is both the process and product of creative action. To make a transition in education from knowledge as information to be transmitted from teacher to students, to knowledge as design, we have to systematically put the notion of design to work. Perkins (1984; 1986) provided a designerly thinking method to help make this transition. His questions help demonstrate that knowledge is design or the process and product of creative action. These four questions that we ought to ask of any design are essential to putting design to work in the service of demystifying technology:

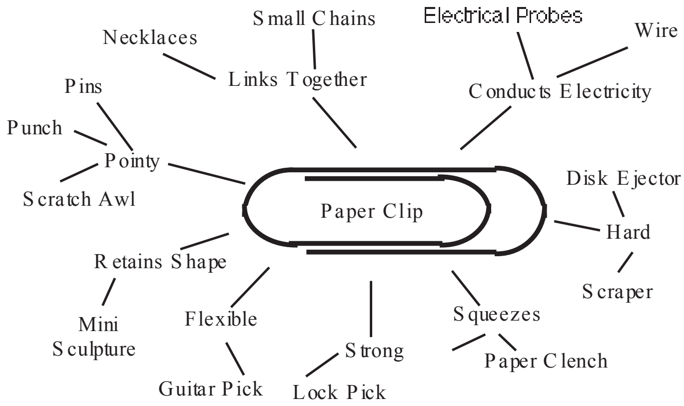
- What is its purpose (or purposes)?
- What is its structure?
- What are model cases (concrete examples)?
- What are the arguments that explain and evaluate it?

Take a paper clip for example. Its purpose is clenching or squeezing paper to aid in arranging and organizing. It can also be used for punching holes in paper, ejecting floppy disks, making mini sculptures, picking locks or an electrical conductor. Paper clips are categorized in the family of fasteners according to their primary purpose. Fasteners function by one or more of the following operational principles:

1. **Adhesion:** Substance with qualities of glue is used to adhere one object to another (glue, tape).
2. **Encircling:** Material wraps around objects (elastic band, string, tape, wire).
3. **Friction:** Objects are clenched or pressed together and friction is increased (bolt, nail, screw, paper clip).
4. **Magnetism:** Magnetic materials are used to increase principle of friction (magnets).
5. **Penetration:** Implement is used to penetrate objects to fasten one to another (nails, pins, thumbtacks).
6. **Squeezing:** Objects are clenched together with some implement which increases friction (clothes pin, paper clip).
7. **Static:** A static charge is induced which serves to bond two material together.

The question of the structure of paper clips can refer to its major materials, parts, material or operational properties, relations, shape and so on. For any design, we can simply identify structural features that are most illuminating and revealing. Common paper clips consist of a single strand of steel wire that is bent in three places

Figure 2. Purposes of a paper clip



to allow for the separation of one part from another. Plastic paper clips are built on a similar design. A paper clip can easily be constructed, drawn or found to provide a model of its structure. Any single, common paper clip can be used as a model to demonstrate the function of all paper clips (Figure 2).

An argument or evaluation can easily be made on why the paper clip works (engineering, science) and why its designed the way it is (aesthetics, history, material properties). Principles of physics, material properties, and the process of clenching can be brought to bear on the argument. For example, friction typically increases when objects are squeezed together. Different paper clips can be compared and evaluated through pros and cons about their designs. We can evaluate the elegant simplicity of the paper clip through aesthetic principles. Their simplicity adds to their ecological sensitivity. Paper clips are extremely ecological in that they require a small amount of material to produce and are nearly infinitely reusable. In theory, no paper clips should be wasted; no paper clips should end up in the waste can. We can explain why some work better than others and why some are more aesthetically ornate than others. Paper clips are universal and will clench any paper anywhere at anytime. The first bent wire paper clip was patented in 1867 and by the mid 1890s, paper clips had made pins obsolete as fasteners for paper. The production of paper clips capitalized on the widespread availability of steel wire in the late 1800s and the design of machinery that could reliably and automatically bend the wire into paper clips for pennies per box (Petroski, 1992, p. 60). Paper clip shapes varied by the dozens, reflecting the creative approach that designers took to solving an everyday problem. The marketing of paper clips was competitive, and suppliers boasted that the superiority of their designs rested on certain characteristics:

1. Does not catch, mutilate, or tear papers
2. Does not get tangled with other clips in the box
3. Holds a thick set of papers
4. Holds papers securely
5. Is thinner and takes less space in files
6. Is easily inserted
7. Is light weight and requires less postage
8. Is cheap (because it uses less wire)

We can evaluate the effects of the paper clip on everyday life through McLuhan's Laws of Media. Each artifact or medium, McLuhan and his students (1988, 1989) argued, can be analyzed through its effects, or through what the artifact enhances, retrieves, reverses into and obsolesces. These laws help us understand the structure of all artifacts and reveal the hidden effects, meanings, and properties of media. We can begin by asking four questions of any artifact:

1. What does any artifact enlarge or enhance?
2. What does it erode or obsolesce?
3. What does it retrieve that had been earlier obsolesced?
4. What does it reverse or flip into when pushed to the limits of its potential?

In a two by two tetrad form, the Laws of Media can be used for the paper clip. The paper clip is a microcosm of the larger world of design, production, and consumption.

Enhances Organization, consumption, aesthetic variety	Paper Clip	***Reverses into*** Obsession with Neatness, Gadgets
Retrieves Convenience, Simplicity, Temporality		***Obsolesces*** Pins, Permanence

In summary, our disclosive analysis of a paper clip includes knowledge about purpose, structure, models, and argument (evaluation). We do not fully understand a design until we understand these four things about the design. By using these four questions to interrogate concrete and abstract designs, students come to understand a theory of knowledge where knowledge is dynamic and generative. This theory helps to contradict traditional theories of knowledge and teaching where knowledge is inert information and the teacher is the purveyor of this information.

But to treat knowledge as design, the four questions must be extended to abstract things, such as insurance policies or the Pythagorean theorem. What is the purpose (or purposes) of an insurance policy? What is the structure of these policies? What are model cases (concrete examples) of insurance policies? What are the arguments that explain and evaluate insurance? What of the Pythagorean theorem? Can we teach students a designerly disposition to the world? Can we help them understand the dynamic nature of knowledge?

Design and Problem-Solving

Creativity and design often take the form of abstract situations that require a highly developed use of the imagination and intellect. However, students do not necessarily have the aptitude to immediately handle the abstractions of design. The teacher's challenge is to arrange for the conditions that ground abstract problems. While abstract problems are a necessity of design, the degree to which these problems are confidently handled and successfully solved is dependent on our ability to make these problems concrete. The first condition for problem-solving in technology is that problems can be made concrete (DeLuca, 1991).

The ability to design, to solve design problems, is also dependent on a range of factors and traits. As indicated, one important characteristic is a designerly disposition toward knowledge. To adopt a designerly disposition is to see knowledge as dynamic. There are four important characteristics that govern creativity in the solution of design problems (Zanker, 1971, p. 43):

- The ability, held by an individual or group, to identify the situation which generates the basis of the problem.
- An ability to isolate the megastructure of the problem and to see clearly the constituent elements within this.
- A divergent and unblinkered ability to think around the problem in an inventive and perceptive way.
- The determination to succeed at all costs should not be influenced by known solutions as unsatisfactory elements.

Creativity, ingenuity, design, and problem-solving require the teaching of designerly dispositions. At issue here is not whether dispositions should be taught. The issue is how designerly dispositions are best taught. Although there are and were a few exceptions, educators teach and taught the dispositions of design and problem-solving by focusing on methods, or what some call "soft skills." The premise was that by learning a method, or "soft skills" of problem-solving, students would discipline their minds to methodically recognize and address problems of various kinds.

The problem-solving method was derived from scientific (hypothetico deductive) methods, which Dewey (1910, 1929, 1933) and Polya (1945/1957) made popular in education. Dozens of problem-solving methods or models were derived from four basic steps:

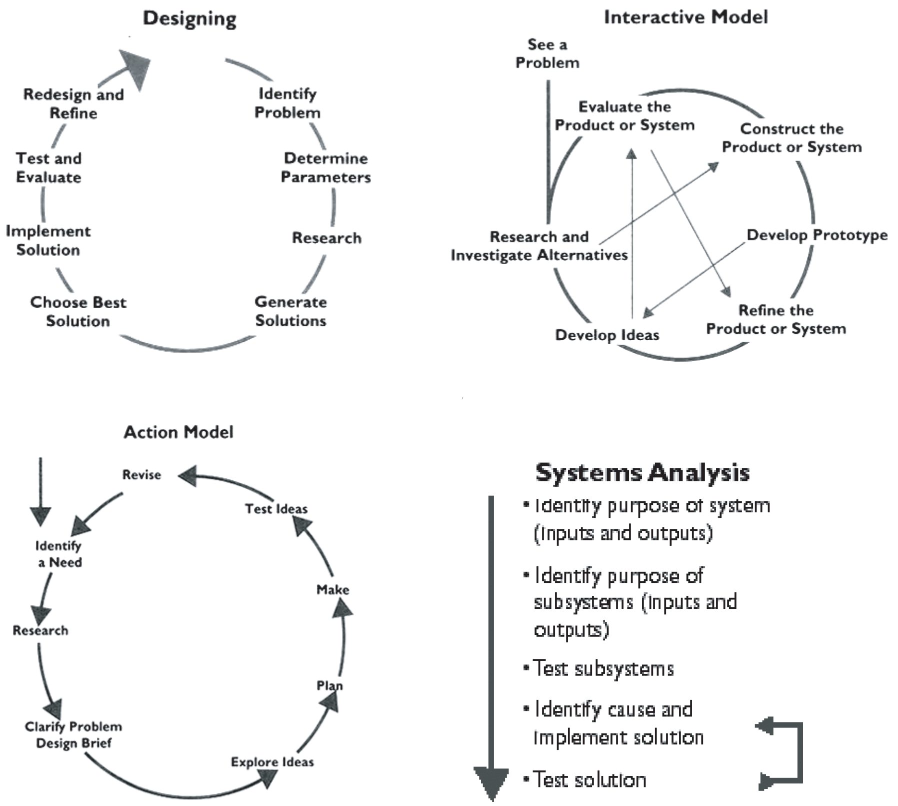
1. *Find*, understand, and represent the problem
2. *Devise* a plan
3. *Execute* the plan
4. *Check* the solution and reflect to consolidate learning

Dewey and Polya wanted students to learn a generic scientific method in schools and expected that the method would transfer to everyday, real world problems. They argued that the problem-solving method was universal and applicable to all problems, anywhere, at all times. As long as students were using a problem-solving method, it was assumed that they were solving problems. In effect, the method came to be a routine school procedure that had less to do with the resolution of problems than with the methods of schooling. For example, the method provides teachers with a structure for classroom management: everyone defines their problem by today, develops four alternative solutions by tomorrow, designs a prototype by the next day and so on. In technology studies, the problem-solving method, called "the technological method," is as overused as it is in other subject areas (Savage & Sterry, 1990, p. 6). This method (identify and represent a problem, generate solutions, choose, model, and test the best solutions, and implement and evaluate the design) is also generic to designers and systems engineers. And as Romiszowski (1981, p. 8) suggested, it is also generic to educational technologists. The technological method is a step by step process of design and problem-solving.

Technological Method:

1. *Defining* the problem
2. *Developing* alternative solutions
3. *Selecting* a solution
4. *Implementing* and evaluating
5. *Redesigning* the solution
6. *Interpreting* the solution

Figure 3. Models of design and problem solving (BC MOE, 1997)



Design Method

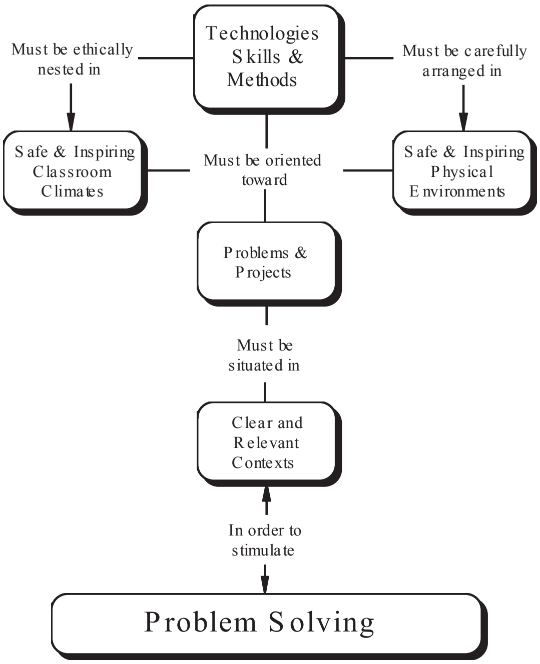
1. *Generating*, or envisioning future states of affairs
2. *Modeling*, or providing descriptions of these states
3. *Testing*, or analyzing their feasibility

All of these variations on the basic problem-solving method seemingly capture, in general terms, the essences of what are somewhat visible and politically correct. They neglect the essences of the distasteful practices of problem-solving and design (Figure 3) (BC MOE, 1997).

The questions for researchers and teachers are: do these methods work? Is this how designers, engineers or technologists solve problems? Are these the most important essences of problem-solving, or are there others that are ignored in these models? Problem-solving, like creativity and design, is a misunderstood and overused concept in the vocabulary of teaching methods, phrases and terms. The use of problem-solving methods has become a ritual, some have suggested, having more to do with classroom culture than actual problem-solving. In short, the problem-solving methods provided above have been found to bear little resemblance to the way problems are solved in everyday life or the way that designers, engineers, and scientists do their work. They are simplified, rules of thumb that students should learn nonetheless. There is a fundamental discipline built into the methods that students ought to adopt in solving problems. But research suggests that teachers ought to move fairly rapidly from the basic to more sophisticated models with their students.

Extensive reviews of research on thinking and learning suggest that problem-solving involves whole brain functions and is an innate human capacity. Humans generally function through three steps in inquiry: (1) searching for and rendering of a context for problems, (2) ordering of details and information, and (3) decision making, evaluation, or conclusion. In an initial stage of problem-solving, the problem solver searches for problems or for insight into the context of the problem, and generates a picture of the problem at hand. Similarly, research on learning suggests that in initial stages of the learning process, about three quarters of learners prefer broad,

Figure 4. Instructional design for problem solving



holistic and contextual pictures to provide meaning and insight into the nature of ensuing events. Hence, there is evidence that problem solving, and to a large degree learning, begins with contexts—big pictures. By establishing a context for problems, we generate meaning and purposes for creativity, design, and problem-solving. A study of political decision making and problem solving has suggested that the first question in problem solving is not "what's the problem?" but rather "what's the story?" (Clark, 1988, p. 22).

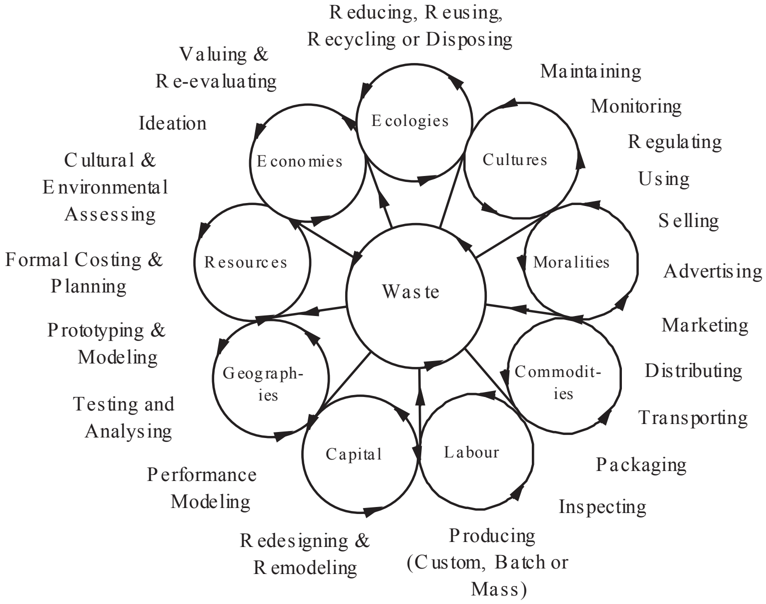
The psychology of motivation speaks to the importance of relevance. Theory and practice in problem-solving should recognize the significance of both context and relevance. If the search for context and meaning is accepted as an initial and significant part of problems, a challenge for teachers is to guide students into and through contexts that are problem rich. The challenge is to establish contexts that are relevant (Figure 4). Of course, problems are neither found nor solved in vacuums and students are generally aware of this. They are always contexts nested within contexts, whether teachers choose to identify these or not (DeLuca, 1991, 1992).

The Ecology of Design and Problem-Solving

There are two major changes that characterize the current state of theory in design and technological problem-solving. The first shift is from product design to lifestyle design. The second is from problem-solving to problem life cycle. Both of these changes reflect a deep regard for ecology and the state of the environment. No longer can design be simplified as the intuitive creation of individuals working independent of nature. While design and technological problem-solving involve a Web of natural and social relations, one of their failures has been a lack of sensitivity toward the complexity of life within this Web. This insensitivity has been reinforced through a near total reliance on the conventional methods described earlier.

An alternative is to include critical, dynamic essences in product life cycles and to design for sustainability. In an ecocentric model of design, rather than any static inputs and outputs or means and ends, the focus is on conditions and processes of design and technology (Figure 5). In the model provided below, which is intended to be ecocentric, the process of waste is the pivotal center around which the other cycles revolve. Each of the ten cycles combine to create, and are integral to holding together, a larger product life cycle. Of course, these cycles are inseparable but are separated here for clarity. For example, one does not "use" resources without disrupting someone's cultures, ecologies, and geographies. It is not important which cycle you start with, as long as all the cycles are attended to their interrelations within any given design or technological problem. Contrary to simple methodological "how to" models in design and technology education, this model is helpful in accounting for the life cycle of design and problem-solving.

Figure 5. Life cycle of design



The emphasis is on awareness and prevention in order to break our current cycle of production—consumption—waste. It is crucial that we leave open the option that, in school, a design or technological problem may be halted for lack of accountability to an ecologically sustainable resource stream. Another option is that thirty student problems or projects may be consolidated into two small-scale problems. There are difficult questions to address: If we know little about the resource stream in which our materials arrive, ought we produce anything at all? If we slow down or halt production and consumption in design and technology education, can we still teach? What is our ecological footprint? Students ought to be encouraged to do nothing less than ask and answer some difficult questions of ecodesign (Petrina, 2000):

- Where do our materials come from—from whose backyard and at what ecological cost?
- How did the materials get here—through whose backyard and at what ecological cost?
- Where does the waste of our production and consumption go—to whose backyard and at what ecological cost?
- How do I change my lifestyle to produce and consume less?

- How much embodied energy does the product or process require over time? (Embodied energy refers to the amount of energy necessary for the production of materials in the product or process)
- Are renewable or sustainable resources used in the product or process?
- Are there less energy-intensive, longer lived alternatives to the resources used?
- Whose resources and labor was used in extraction and manufacturing?
- Are local resources for the product available?
- What hazardous, gaseous, aqueous, or solid wastes are created? What ecologies and people are exposed to this waste in extraction, construction or manufacturing?
- Can this waste be reduced through alternative materials and techniques?
- Does the product require special techniques, treatments, or finishes that are health and safety hazards?
- How much energy is required for transporting the materials and product?
- How easy is it to maintain and recycle the product?
- How much maintenance does the product require over its life?
- How resource-intensive is the maintenance program?
- What wastes are produced in maintenance? Who will maintain the product or process?
- Can the product be recycled or reused at the end of its useful life?
- Do different materials offer better chances of resource recovery at the end of the product's life?

Our challenge is greater than teaching design and technological problem-solving in a way that merely results in "making stuff and doing things." Despite all the questions that we may ask in the name of greening our "making and doing," current research suggests that design is about lifestyles. As noted in Chapter III, design is about controlling environments, experiences and emotions. We have to face the reduction of waste issue inside and outside of school. Good design and technology education is about reduction in production and consumption. In technology studies, we demystify the processes and products of design through disclosive analysis.

Life Cycle Assessment, Resource Stream, and Footprint

Product life cycle, or life cycle assessment (LCA) began as an engineering design model for analyzing products over the course of expected and actual lifetimes—from cradle to grave. Early design issues focused on stages of product introduction, growth, maturity, and decline, much as technology assessment dealt with stages of invention, development, innovation, and diffusion. The idea was that decisions on engineering feasibility at early stages in the design of a technology were to be fully informed by knowledge of parts and product affordability, availability, usability, repairability, reliability, and disposability. In life cycle models, product design, production, use, and disposal are the same issue: design for life. LCA eventually became concerned with sustainability, and became a way of accounting for material flows or streams from "cradle to grave." The life cycle of technologies came to be seen as intricately interrelated with life cycles of living organisms.

The premise of LCA is that by thinking in terms of material or resource streams we can avoid malignant production practices and reduce our net consumption. The emphasis is on awareness and prevention in order to break our current cycle of production—consumption—pollution. The emphasis is also on interconnectedness and sustainability. Resource stream is an ecocentric method that traces the flow of materials from their *extraction* through their incorporation into part and product *production* and their ultimate *disposal*. Resource streams make visible the fact that *materials* are extracted and refined, and manufactured into parts and products, which are consumed, used and maintained. Products and materials with no remaining *value* are discarded with percentages of the waste being either disposed, dispersed, or recycled. A resource stream suggests that within any technology, through capital and labor some material was extracted from some(one's) place and harnessed for some use over time with some waste along the way and in the end. Accountability and sustainability mean that all costs—ecological, cultural, social—and not merely economic costs are figured into design decisions. Establishing a clear, visible account for resource streams is central to the LCA and ecological footprint analysis.

The ecological footprint analysis was developed to account for resource streams (Wackernagel & Rees, 1996, p. 3). The ecological footprint "accounts for the flows of energy and matter to and from any defined economy and converts these into the corresponding land/water area required from nature to support these flows." Wackernagel and Rees argue that we account for our resource consumption and waste assimilation requirements in terms of land area, or footprint. The footprint represents the "appropriated carrying capacity" of terrestrial ecosystems necessary to support a given person, society, country or product (p. 11). This appropriated area necessary to support the habits of affluent countries has gradually increased throughout this century. The current ecological footprint of a typical North American is "three times his/her fair share of the Earth's bounty. Indeed, if everyone on Earth lived like the average Canadian or American, we would need at least three such planets to live sustainably" (p. 13). A planet where everyone imposes an over-sized footprint is not sustainable. The ecological footprint puts our accounting of resource streams into local and global perspectives. Ecological footprint analysis helps teachers and students disclose the natural consequences of products and processes by quantifying land and water use (Formula and automated strategies are available on the Web).

Disclosive Analysis

Disclosive analysis refers to a group of methods that are used to derive meaning from the artificial and natural worlds. In the next chapter, we explain the theory behind disclosive analysis. This section provides a description of disclosive methods of analysis. The most common disclosive methods for technology teachers include basic causes, designerly thinking, ecological footprints, laws of media, life cycle assessment, quotidian deconstruction, resource streams, reverse engineering, socio-logics, systems analysis, technology assessment, and forecasting.

Designerly Thinking and Laws of Media

In a previous section, we introduced the notion of designerly thinking to help us think about knowledge in dynamic terms. The four basic questions that Perkins (1984, 1986) provided help us disclose the conditions and workings of individual designs or technologies:

1. What is its purpose (or purposes)?
2. What is its structure?
3. What are model cases (concrete examples)?
4. What are the arguments that explain and evaluate it?

We also outlined McLuhan's laws of media. These laws help us understand the structure of all technologies and reveal their hidden effects, meanings and properties. The laws of media form a two by two tetrad for each technology. For example, the laws of media that govern cable television can be disclosed by asking the following four questions:

Enhances Quality and diversity of signal pick-up	Cable TV	***Reverses into*** Flip to home broadcasting
Retrieves Early transmission broadcast pattern point-to-point		***Obsolesces*** Diffuse broadcasting

Again, we cannot stop with surface features. For McLuhan, the laws of media should be used to penetrate the inner workings of media and disclose forces and politics that are hidden or taken for granted.

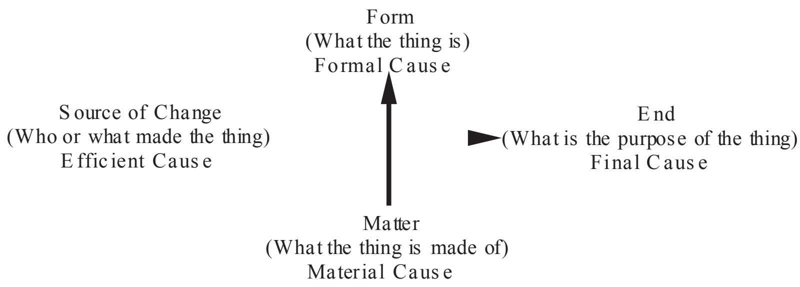
Basic Causes

Disclosive analysis generally originated with Aristotle who, in *The Physics*, identified four basic causes that explain why artificial and natural things are as they are. His logic was practical: Instead of merely accepting things as we see them, we have to explain and interpret things. Marx would later challenge this by arguing that the intent of interpretation was to change things. Aristotle asked: why is a statue a statue? What causes a statue to be a statue? He suggested that there were four causes that explain why things are as they are. There are four different explanations for natural and material things (Figure 6). The four explanations answer to four different sorts of questions:

1. What is it made of?
2. What sort of thing is it?
3. What brought it about?
4. What is the purpose of the thing?

These questions correspond to his four causes: (1) Material cause, (2) Formal cause, (3) Efficient cause, and (4) Final cause. Some philosophers dubbed these the four becauses to emphasize that they are explanations. They do not relate to the way that we tend to think of causation, as in cause-effect. Aristotle's method has also been called an etiological analysis (inquiry into causes).

Figure 6. Aristotle's four causes



Teachers can assist their students to do disclosive analyses to interpret the technologies they use or produce. The four basic causes can be used to disclose a story behind things that is hidden or distorted. Aristotle's causes disclose a story of material, form, force, and function. How can we explain a table using the four basic causes? At first glance, the table's matter, form and function seem obvious. We can simply say that the table is made of wood. It takes the form of four legs and a flat top. We can surmise that a carpenter made the table. It serves the functions of eating and writing. This would be an analysis that dealt strictly with surface features. Disclosive analyses must penetrate the surface of things, as Aristotle prescribed. Why was wood used? Where did it come from? Why does the table take the form that it takes? What were the conditions under which the carpenter worked? Was it primarily machine produced? Is the purpose of the table purely functional? What happens when it comes into use?

Quotidian Deconstruction

Quotidian deconstruction is a form of disclosive analysis that focuses on the feelings that people derive from their quotidian or everyday experiences with technology (Feng, 2003). The intention is to show how we *experience* culture, nature, and technology in tandem. Quotidian deconstruction enables students to realize that technology is nature transformed (as nature formed into technology) and culture is technology transformed (as everyday, mundane technologies, like buttons, spoons or utensils, formed into culture). Students focus on their everyday life with technology and use phenomenology to help them disclose their desires and feelings about culture, nature, and technology. There are two basic directions to this method of disclosive analysis. The first is toward deconstruction by connecting everyday technologies to their natural sources. Feng uses the example of a clay spoon that has its source in the mud of a riverbed in China. The second is toward phenomenology by connecting the same technology to personal experiences. Here, the spoon provokes personal meanings and memories for its users. Things have value well beyond their economic and functional value. Phenomenology means that we express how we experience something, prior to any theorizing about it. We deal with the raw feelings and experiences. The experiences disclosed may be traumatic or we may have fond memories. The goal is to let the artifacts speak in the two directions outlined: toward their source (material form) and the way we experience them (phenomenology). The everyday technologies that we use hold stories and disclose our feelings toward them. Quotidian deconstruction is a way of letting these stories emerge with our feelings.

Reverse Engineering

Reverse engineering is a method wherein we figuratively and literally disassemble a technology to figure out how it works. It is the physical deconstruction equivalent of our methods of conceptual deconstruction. The method is common in business and industry where the ability to equal or outdo competitors is dependent on innovation and the introduction of competitive products into the market. Reverse engineering is prevalent in the hardware and software industries. Knock-offs or imitations *via* the disclosure of trade secrets are common. Reverse engineering requires that we physically *and* analytically disassemble the technologies of interest. Physical disassembly requires that we work backwards from the finished product and part by part reduce it to its simplest components. We figure out the *application* of the components and how they relate to each other. Analytical disassembly requires that we work backwards from the finished product and, process by process, deduce the mathematical and scientific concepts or principles underlying the processes. We figure out the *explanation* of the processes and how they relate to the whole. This method is common to the math-science-technology (MST) approach to integration that is described in Chapter VII (Sanders, 1994).

Sociologics

Sociologics is a controversial issues method particularly suited to help us to deal with controversy in design, science and technology, or technoscience. Sociologics was developed by Bruno Latour in his now classic book *Science in Action*. What makes design and technoscience exciting, said Latour, is the fact that alternative and competing arguments and products are developed and pursued. And what makes these controversial is the increasingly important role they play in our health, livelihoods

Table 1. Sociologics of controversies

1. **Causality:** How are causes and effects attributed? What causes what in the controversy and in people's points of view?
2. **Mapping:** What points of view are linked to which other points of view? Who is saying what about what?
3. **Credibility:** How credible are the points of view? What are the strengths of the links between points of views?
4. **Legitimacy:** Who and what have a voice or role in the controversy? Who is excluded and why?
5. **Movement and change:** How are the design and technologies modified in the arguments? How are the arguments modified in the controversy?
6. **Resolution:** How will the controversy be settled or resolved? What are the options?

and future. Basically, any design or technology has controversial issues associated with it and sociologics helps teachers address these issues. In a general framework of the controversial issues method (Chapter IV), sociologics is organized around five specific questions to ask of the controversy of interests (e.g., disability access, solar power, toxic waste). Working through the five questions helps students understand the logical and political ways in which controversies are formed, addressed and resolved (Fountain, 2001).

Systems Analysis

There are two core concepts to design: sustainability and interconnectedness. Systems analysis helps us to deal with the second concept. Systems analysis is a method of for analyzing human-machine and machine-machine interconnections by determining the inputs and outputs of a given system. This is an effective method of disclosive analysis for demystifying the operations and inner workings of natural, social or technical systems. When we cast a technical system into a larger context we can analyze the interconnections among natural, social or technical systems. Figure 5 is the classic depiction of a system (inputs, processes, outputs, and feedback). Figure 6 is a depiction of the interaction of systems.

Technical systems, like ecosystems, are never truly isolated, even though we treat them as such. To identify a system, we must locate where one system or subsystem ends and another begins. We must make some system components visible and leave others invisible. In a systems analysis, it is necessary to identify what the system involves (i.e., energy, processes, resources, effects). It is important to identify individual components of the system. The key to a systems analysis is identifying why a system operates as a system. In systems analysis, we use a simple procedural method (systems analysis method):

1. Identify the system.
2. Conceptually or physically locate and isolate components and sub-systems.
3. Identify inputs and outputs.
4. Identify feedback mechanisms.
5. Identify or deduce processes.
6. Analyze, troubleshoot, maintain or redesign system.

Sociotechnical systems are a bit more complex in that we must analyze the *interface* between human (social) and non-human (technological) systems. The key is to identify human and machine behaviors and the interconnectedness between the two. Primary interests in sociotechnical systems analysis focus on *relationships* among components in a dynamic system, rather than components themselves. The behavior, goal, or state of a particular system is dependent on cultural, social and technical *components* being coordinated in some way. The components are *coproducers* of outcomes or states, and have distinctive characteristics that must necessarily be respected or *variance* (unprogrammed events) is a result. When the *compatibility* of components is respected, the probability of variance is reduced. Making certain that components interact harmoniously requires that characteristics are respected and correlated in both initial *design* and in progressive *use*. The aim for sociotechnical systems designers is the joint optimization of natural, social and technical systems. Sociotechnical systems analysis requires a knowledge of the way machines and technical systems behave and of the way people and social groups behave. Ecosystems analysis requires that we identify the workings and interconnections among organisms in the ecosystem. Hence, their a number of systems that students can analyze under the teacher's guidance (e.g., technical systems, sociotechnical systems, ecosystems, economic systems).

Separate systems analyses ought to help students understand the contextual and interdependent nature of systems. All systems have contexts (e.g., economic, social, political). Contexts constitute the designs and uses of technologies. Systems analysis, or specifically contextualism, underscores the idea that technology does not develop in a vacuum. Cultural, social and psychological systems are interdependent with technical systems. Currently, theorists of technology are analyzing systems collectively, rather than separately. They analyze collectives of economic, political, social, and technical elements to understand how separate systems interact or dissolve in collectives. In contextualism, technologies shape contexts and contexts shape the technologies in return, more or less in tandem. In interactionism, technologies and other systems are shaped together, simultaneously. Contextualists and interactionists reason that technologies are neither as easily changed as non-determinists argue nor are they as durable as determinists posit (see Chapter III).

Technology Assessment

Technology assessment (TA) is a specific form of disclosive analysis that refers to any methods or processes that are used to assess the measures and consequences (intended, indirect, unintended) of individual technologies or systems of technologies. The consequences of any technology may be collateral (immediate) or deferred (delayed). TA is "the process of identifying the actual or potential secondary effects of a technological development (or set of interrelated technological developments) on social, political, economic, and/or environmental values or institutions" (quoted in Petrina, 1990). TA focuses on all stages of technology, from invention, development, innovation, and diffusion to eventual obsolescence. TA affords citizens (e.g., students) and governmental planners the opportunity to anticipate potential technological developments and their possible collateral, unintended, indirect or deferred consequences. Any given TA should:

1. Describe the specific technological measure and its consequences.
2. Specify viable alternatives based on the distribution of a variety of costs and benefits among affected parties.
3. Present social choices and policy options compatible with a wide spectrum of future scenarios.

The process of TA means underlining the collateral effects of a specific technology and revealing unstable features of this measure, which may lead to long-deferred consequences. TA may dictate effective remedial or preventive actions. TA was institutionalized during the 1960s and 1970s to guide public policy. Technology studies adopted the techniques of TA to assist students in learning to assess certain technologies as well as use these them. TA in the labs and workshops basically involves telling a story of a technology. When our students undertake this challenge, they must analyze the consequences and effects of this technology. Have your students work through the questions listed in Table 2 when analyzing their technology.

The methods and techniques used in TA range from the purely intuitive to purely extrapolative. All too often, TA in the schools simply involves a balance sheet of

Table 2. Technology assessment (Adapted from Marker 1987)

1.	List all the effects you can think of for *one* technological development.
2.	Categorize the consequences on your list according to whether they were intended, planned, and/or foreseen by those who introduced or eagerly adopted the innovation or were unplanned, unforeseen and unintended.
3.	Indicate which consequences were felt only in a local area, which were felt regionally, nationally or globally.
4.	Classify the consequences as beneficial or harmful, or both.
5.	List four factors (values) you consider to be essential to a good quality environment for humans, and which influenced your choice in item #4.
6.	Which subgroups in society benefited most from the technology you are assessing? Which subgroups of society bear (or did bear) the majority of the harmful effects? List two reasons for the inequitable distribution of benefit and burden.
7.	What was the time lapse between: (a) the invention that made the technology possible and its widespread innovation (adoption and diffusion)? (b) between the planned benefits and the appearance and/or the awareness of the burdens?
8.	What actions were or are being taken to alleviate the burdens? Who (e.g., consumers, industry or government) are taking these actions? Who is paying the cost of alleviating these burdens in money? Who is paying the cost of alleviating these burdens in Quality of Life?
9.	What areas of CHOICE did the technology open up for individuals?
10.	What choices or rights did the technology open up for society in general (seen most likely) in legislative and judicial decisions? What choices or rights were compromised?

positive and negative impacts. This type of cost-benefit analysis trivializes the process. The process of TA typically requires that students draw on any of a range of techniques: Historical survey, input-output analysis, cost-benefit analysis, systems analysis, risk analysis, simulation, trend analysis, news analysis and interviews. Technology assessments can be general, where the students try to be as comprehensive as possible in analyzing cultural, economic, ecological, psychological, and social consequences. Or students may concentrate on certain consequences, such as the effects of new technologies on rights.

Technological Forecasting

Technological forecasting (TF) refers to any method that is used to predict the future development of technologies. TF is "a prediction of the future characteristics or applications of useful machines, techniques, or procedures" (quoted in Petrina, 1990). TF most generally is the forecasting of technological change, or the invention, innovation or diffusion of an individual technology or system of technologies. TF should help to provide not only an indication of what future technologies will be, but also the amount of time that will likely involve the developmental stages of a new technology. TF can help to provide an indication of a point in time when an older technology should be abandoned or replaced. Technological forecasters attempt to (a) analyze a specific allotment of resources (capital and knowledge), (b) project the likelihood of achieving technological developments or capabilities within a given period of time, (c) project the implications and contingencies that may affect the realization of such developments or capabilities, (d) project alternative means of achieving a certain capability, and (e) project alternatives to technological change. For the most part, the scope of TF is generally limited to technical factors of future technological change. Social and cultural consequences of potential technological change are not outcomes of TF. Hence, TF may be integrated or supplemented with economic, political or social forecasting. Plausible and apparent technological changes often become topics of interest for technology assessors. TF typically involves trend extrapolation, impact analyses, scenarios, simulations or analogy and provides us with an idea of the probable changes that will take place within a certain period in the future. Exploratory methods help forecasters project future developments based on history, patterns of growth and technological activity. Forecasting is not a psychic way of divining the future. TF is a trends-based method that draws on a modicum of insight, intuition and courage.

The value of an education is increasingly measured by the degree to which it is future oriented. Advocates of forecasting note that TF heightens our perceptions of current problems. Futurism, or concern for the future, is mentally healthy and helps one to develop self-esteem, goal-orientation and organizational qualities. Futurism deals with descriptions of probable alternative futures and the probabili-

Table 3. Technological forecasting

1. Survey a range of resources (e.g., historical data, Web sites such as Futurist.com, etc.) to extrapolate trends and generate scenarios. Remember, technological forecasting is not pure fiction, but is based on trends and extrapolations.
2. Focus on one economic or technological sector (e.g., business, communication, entertainment, health, manufacturing, residential, sport, etc.).
3. List five plausible developments in a single sector or industry in fiver year base projections into the future (i.e., 5, 10, 15, and 20 years).
4. Choose one development at one point in time and represent it as best as possible (drawings, words, graphs, etc.).
5. Provide a brief scenario for this development that you are forecasting. Provide a description of how the invention will be used, what its consequences may be and the way it will be created and disseminated. The scenario may be dystopian, utopian, or mundane.
6. Provide a brief scenario for planning now to enhance the probability that the forecasted technology will be introduced.

ties of their coming into existence. Futurism is based on the premise that although anything is possible, there are aspects of the future that are highly probable and others that are next to impossible. Just as TA and history are beneficial in assessing the characteristics of change, futurism and TF can help students to anticipate certain changes. Most students find TF to be quite interesting, and even entrepreneurial when it comes to their own variations on existing designs. Although TF provides us with an estimation of future changes, it can also help students evaluate, choose and develop technologies that might best accommodate our cultural, ecological, physical, psychological, and social needs.

Design Briefs

Design briefs are a popular form for challenging students to think creatively and systemically to resolve design-oriented problems. They are the standard form for communicating technological challenges and design specifications. Design briefs are popular in the design fields as well as commerce. In these fields, the design brief may be a contract that is quite complex. All design briefs have common elements. There is descriptive information that sets the stage. There is a section that states the problem to be resolved and a section that describes any special conditions. There is a section that describes any special responsibilities of the designers.

Design briefs used in design and technology courses abbreviate all of these components. The design brief in technology courses is a short, professional document, at most two pages. It is used to focus the efforts of the student designers. They are one of the most common forms found in technology studies. Design briefs provide an example of how designers actually focus themselves while providing an educational problem-solving experience.

Design briefs can address a range of design challenges. A typical skill-building project, where all students more or less follow the same plans, can be presented in the form of a design brief (or what some call a project brief). For the sake of simplicity, design challenges can take one of two forms. Design challenges may be either *dynamic* or *static*. Dynamic designs are defined by a series of animations or moving parts driven by some power source, including gravity or human energy. Static designs, such as a brochure or table, are defined by the lack of moving parts (a paper that opens along a crease or drawer do not qualify as moving parts). Design briefs can, like design, present students with open-ended or closed problems, or a combination of the two.

The design brief is not merely a single-use document that is referred to at the beginning of the design process. It is referenced throughout the process to ensure that the solution being developed actually fits the problem. It forms the basis for all decisions made by the design team. From a teachers perspective, it is used as a reference point to evaluate the design solutions and to evaluate any other documents submitted by the design team. While design briefs differ from task to task, most share a number of the components in the following format. This is a commonly used format and the standard in technology studies. The example provided is a good example of how a simple challenge can prompt students to think creatively and successfully act on their imagination. It is also a good example of the structure of design briefs.

Table 4. Design brief format

1.	**Title:** Provide a catchy title.
2.	**Background/context**: Provide a short description of the background or setting. This may be a fantasy or realistic context.
3.	**Problem:** State the design problem in clear, concise terms. A clear articulation of the problem situation is essential if the correct problem is to be identified and an appropriate solution found.
4.	**Constraints:** Provide a comprehensive list of restrictions or parameters that help to shape the design solutions without limiting the solutions to one. Use words such as "Must" and "Cannot." Stay sensitive to the problem of too few vs. too many. Do the constraints limit designs to one solution?
5.	**Design considerations:** Provide a list of issues all the students should consider. These considerations should define what makes an effective design--effective versus ineffective. These may be reminders and prompters that are ecological-natural, ethical-personal, existential-spiritual, socio-political, technical-empirical, and ecological.
6.	**Sequence:** Provide a recommended procedure for students to follow. This should give them direction.
7.	**Related studies:** Provide a list or description of subjects necessary in order to solve the problem.
8.	**Management issues:** Provide a timeline of dates and times that the students will adhere to.
9.	**Self evaluation:** Provide a way for students to evaluate themselves.
10.	**Assessment:** Provide a scheme that you will use to assess the students and their designs.

Opinions differ on the creation of design briefs. In most cases, design briefs will be prepared prior to the beginning of the design challenge (by the teacher or other professionals). In some cases, the design briefs will be prepared by students, or groups of students working together on a common design problem. Here, teachers and students refine the problem together and the students prepare their design briefs. Either way, it is important to provide a format for the students to follow.

Table 5. Fasten(at)ing technology—paper clips

Context

In the family of fasteners, a paper clip is what you might call a simple, elegant solution to the problem of squeezing or clenching paper. Paper clips are easy to reproduce, easy to use, hold papers together without causing damage or crimping, and have many other uses besides clenching. This is only partially true. Paper clips do cause damage. Some get rusty and stain the paper. Some are too inflexible and leave a permanent crease or crimp in the paper. Your challenge is to improve fastening technologies by designing the perfect paper clip.

Problem

Design and construct a fastener for paper.

Design constraints

1. The fastener must be designed so it is reproducible.
2. The fastener or clench must be made of one or two single, continuous pieces of material.
3. The fastener must hold two and more sheets of paper together.
4. The fastener must be portable and reusable.
5. The fastener must not damage the paper.
6. The fastener can be made from any material.
7. The design must be scalable (e.g., from paper clip to money clip)

Design considerations

- Pay close attention to the elegant function of the fastener: does it effectively clench?
- Consider a wide range of possible fastener designs.
- Review the range of paper clip designs presented, but do not duplicate these.
- Is the fastener reproducible and scalable?

Construction Sequence

1. Brainstorm ideas for the fastener's operation and appearance.
2. Sketch four or five designs and choose appropriate features, forms and materials.
3. May use 2D computer aided design (CAD) or 3D modeling techniques to lay out mechanisms and parts.
4. Locate recycled materials or new materials.

Table 5. continued

5. Test the materials for the properties.
6. Bend and finish the final prototype fastener.
7. Test the fastener.

Management Issues

- **End of day 1:** Approval of fastener ideas.
- **End of day 2:** Fastener prototype and sketches explained, presented and submitted.

Related studies

- Physics
- Business
- Social Studies
- Sociology
- Psychology
- Engineering

Honest self (group) evaluation

1. We stayed within the design constraints and deadlines.	______ out of 5 marks
2. Our fastener is unique in its design.	______ out of 5 marks
3. Our fastener has makes effective use of materials.	______ out of 5 marks
4. Most of the excess materials can be reused or recycled.	______ out of 5 marks
5. Our use of materials was creative, economic, and efficient.	______ out of 5 marks
6. Our fastener successfully satisfies all the design brief requirements (i.e., holds two and more sheets of paper together; is portable, reproducible, reusable, scalable).	______ out of 5 marks
7. The demonstration of our fastener was creative and entertaining.	______ out of 5 marks
Total	out of 35

Assessment

Group's self assessment	________ Total/ 35
Design principles	
Features and form	________ out of 10
Originality	________ out of 10
Economics and ecology	________ out of 10
Craft and quality	________ out of 10
Clenchability	________ out of 15

Projection and Reflective Practice

In this chapter, we reviewed the current state of research into creativity, design and problem-solving. We explained how creativity, design, and problem-solving were connected. We emphasized that at the core of creative practice are dispositions. Among the most primary of these dispositions is designerly thinking, or the will to see knowledge as designed. Educators adopted a number of techniques to develop dispositions toward creative problem-solving and the most important of these is the design brief. These techniques are what some analysts of career preparation and human resource development call "soft skills." In the next chapter, we will expand on our theoretical framework for the practice of creativity, design and problem-solving. Before moving to the next chapter, complete the design brief challenge for teachers below.

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Section II

Analyzing and Designing Technology-Based Curriculum

Chapter VI

Learning Theory, Technology and Practice

Introduction

Why do we use technologies in technology studies? Couldn't we teach technology in a classroom without the complex lab and workshop infrastructures that characterizes technology studies? We could argue that this is by tradition; this is the way it always was. We could argue that we are involved in training students for occupations that use the technologies we use. We could argue that technology is naturally practical and demands that we offer practical activities. Tradition, vocation, or imitation. Not one of these three will get us very far. We could argue that students learn best when they are active; enactive experiences are best. With this argument, we verge on theoretical issues that underpin technology studies. However, neither experience-based learning nor enactivism account for technologies in any adequate way. We need to retheorize learning theory to make it work for technology studies.

Learning theories deal with specific notions of feelings, knowledge, and skills by addressing the problem of how we learn. Whether we are aware or not, our teaching practices are necessarily shaped by any number of learning theories. We are conditioned or socialized to express particular learning theories through years of participation in schooling and informal education. Sayings such as "we teach who we are" or "we teach how we were taught" suggest the power of our socialization into education. We are all products of our formal schooling and informal education.

The problem is that we are typically not exposed to a *range* of learning theories over time. In fact, we are socialized, through formal and informal education, to believe that knowledge is information that is transmitted from generation tom generation, person-to-person or node-to-node over the internet. We have been socialized to believe that feelings and motor skills are secondary to knowledge and intellectual skills. We have been socialized to accept that, *a la* Plato, a controlling mind is superior to a subservient body. In turn, we were taught to accept that mental labor is more valuable than emotional or physical labor, and the liberal arts are more valuable than the servile arts.

Popular learning theories, such as behaviorism and constructivism, take feelings, skills, and technologies for granted. Or for the most part, these theories reduce feelings, skills, and technologies to an incidental position. They are incidental to an adaptive construction or transmission of knowledge. Biases, against feelings, skills, and technologies due to predominant social values are built into our most common and popular learning theories. New learning theories such as activity theory and situated cognition contradict this hierarchy of head over hand by bringing the body back into the process of learning. Technology educators can either blindly adopt learning theories that undermine their endeavors or search out and develop learning theories that reposition feelings, skills, technologies and knowledge. We absolutely have to embrace learning theories that take technology as a serious subject. Anything less invalidates our existence and the need to study technology in schools.

This chapter begins with a learning theory that derives from practice in technology studies. Indeed, we begin with what is by nature a disclosive theory of practice. We then turn to theories of experiential learning and their implications for technology studies. The chapter concludes with an overview of various learning theories and a focus on distributed cognition and activity theory.

Head, Heart, Hand, and Feet

In the movie *Metropolis*, released in 1929, the protagonist Maria labors to educate the managers and workers of the futuristic, technological city of Metropolis. At one point, in a clandestine meeting with the workers, she pleads for an understanding of a basic arts and crafts premise: “The mediator between brain and hands must be the heart!” This premise appears a number of times throughout Fritz Lang’s film. Most attribute this premise to John Ruskin, philosopher of the English arts and crafts movement during the mid 1800s. This philosophy was ratcheted up during the 1880s in the post-secondary institutions for African Americans in the U.S. south. Booker T. Washington, the intellectual architect of technical education institutions in the south, stressed mobility and the importance of gaining a footing for elevating the status of African Americans. At schools such as the Tuskegee Institute, students were provided with an education in cultivating the soil on seven hundred acres of land. When he transformed the curriculum of the Christiansburg Industrial Institute in the mid 1890s, he changed Tuskegee's basic philosophy into the "heart, head, hand, and feet." The heart stood for compassion, the head for knowledge, the hands for skill, and the feet for the grounding, mobility and the earth.

This philosophy accompanied every form of education for the working classes across the world (Figure 1). For example, Otto Salomon, the Swedish proponent of the Norwegian version of manual training, was fond of making this case in the 1890s. Manual training, or what he called sloyd, was based on a "Harmonious balance" of the head, heart, and hand. This premise underpins the past of technology studies and the same premise underwrites the learning theory of technology studies today.

Technology studies was introduced into American, Canadian, and English schools during the late 1800s and early 1900s under the guise of manual training and the British arts and crafts philosophies of Robert Morris and John Ruskin. The intent of arts and crafts and manual training was to provide simple experiences in hand labor to expose students to working class knowledge, skills, and dispositions. From its earliest days, technology studies was meant to educate "the hand, the head and the heart," as Ruskin argued, "and the feet" as Washington added. Arts and crafts philosophies were critical of capitalism, mass industrialization, the demise of craft skills and knowledge, and the divorce of the arts from industry. But by the mid 1910s, the arts and crafts philosophy on handicraft was sympathetic to industry and the use of machines. Design schools such as the Bauhaus in Germany demonstrated that the use of machines did not have to come at the expense of craft skills and design. Bauhaus students were trained to integrate design with industrial production. In technology studies, the use of machines provided a *disclosive* power for attaining cultural ends; technical skills should disclose democratic dispositions and knowledge. With the use of machines in the workshops of the 1920s, technology teachers were challenged to disclose the problems and promises of production and consumption. With this premise, the subject's most articulate advocate in the 1920s and 1930s, defined industrial arts, as it was called in those days, as "the study of sources of materials, methods of changing materials, factory organization, inventions, employer and labor cooperation, distribution of products, and regulative measures to secure justice alike to producers and consumers" (Bonser, 1930, p. 2). This was quite a sophisticated definition that could nearly serve today as a definition of technology studies. Nevertheless, technical skills dominated as ends in themselves (skills for skill's sake) and the disclosive power of technology was generally neglected. One reason for this is that we have never had clear articulation of theory that accounts for technologies in the learning process.

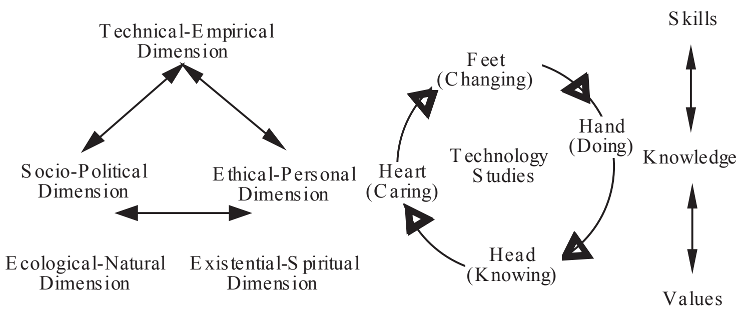
Joseph Luetkemeyer, a professor of mine, used to say that our disclosive theory of practice reiterates the way that technology studies has been formed over time. Prior to formal schooling, handicraft was the primary mode of practice with technology. Craftsmen and craftswomen learned their skills for subsistence or for the sake of the craft and trade. When manual training (MT) entered the schools in the mid 1800s, a psychological premise for doing handicraft was derived from the activity of working with one's hands. At this time, we heard enthusiasts argue the psychological value of MT: Handicraft builds moral character, strengthens the mind, and intrinsically motivates individuals to learn and be industrious. Skills were secondary to psychological values. Throughout the 1900s, a logical organization of content was eventually derived from the activity of working with technology. In the 1960s, logical content structures were established for the subject of technology studies. Both skills and psychological values were secondary to content. Our theory of practice recapitulates our history of practice. The direction is from skills and technologies to values and content.

Feeling and Knowing Issue from Doing

Of course, we have feelings and knowledge prior to, during, and following our practice with technology. And of course teachers often derive curriculum from their students' values and knowledge. However, the point is that, in technology studies, we provoke feelings and knowledge by engaging students in practice. We provoke feelings and knowledge by engaging students in skill development. Pragmatically and theoretically, we use the skills as an intermediary to feelings and knowledge. To say that the use of technologies, or skill development, provokes the heart to care, the head to think, and the feet to move is to say that *skills motivate*. Activity motivates.

This is *not* to say that materials and technologies are merely incidental to or an instrument to larger ends, such as values and knowledge. We can say that our use of materials and technologies, or skill development, is an end in itself (skills for skill's sake). The technologies we use in practice are the subject of study. Skills are

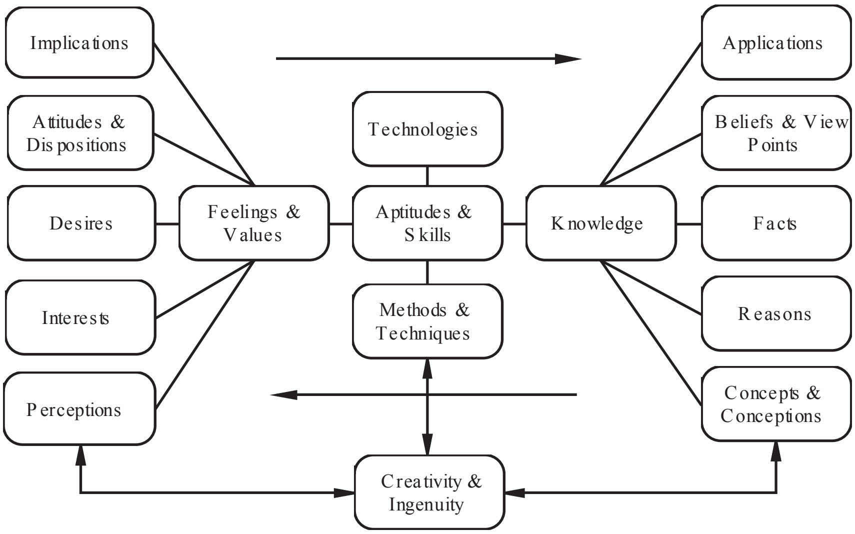
Figure 1. Model of practice in technology studies



prioritized first in our theory of practice, or in our theory of how we learn about, through and for technology. However, we must keep the ends of education in a complex world in perspective. Skills are *no* more important in practice than feelings and knowledge about technology. Sure enough, skills motivate. Sure enough, technology is a subject in its own right. But we cannot stop there. Practice in technology studies is incomplete if restricted to the hand or skills. Practice is incomplete if restricted to the technical-empirical dimension (Figure 1).

In our theory of practice, skills (or engagements with technologies) are used to disclose and provoke feelings and knowledge. This is different than saying that skills or technology are applications of knowledge and values. Skills and technology certainly enrich or reinforce knowledge and values. However, in our theory, skills play the role of revelation and stimulation rather than amplification or fortification. In return, feelings and knowledge empower skills. As described in Chapter II, propositional knowledge and emotions empower procedural knowledge, or skills. Figure 2 reminds us that while skills and technologies may be reliable agents in the construction of knowledge and values, students bring feelings and knowledge to their development of skills and engagement with technologies. We try to accommodate the students' prior knowledge and dispositions by attending to their learning styles and by making parts of the curriculum student-directed. Nevertheless, our task as teachers is to create a curriculum that will move students from the known to the unknown, from the familiar to the unfamiliar and from injustice to justice. As Herbert Thelen asserted, "if we get too comfortable, we stop growing. Students can put pressure on us to work within their comfort zone. Let's be kind about that. Kind enough to let them learn to be uncomfortable" (quoted in Joyce & Weil, 1996,

Figure 2. Instructional model of technology studies



p. 385) In our theory, we use skills to move students from their comfort zones and to new knowledge, dispositions, and values (Figure 2).

In the first three chapters, we more or less distinguished doing from knowing from feeling. We acknowledged that while we differentiate between domains of learning, these domains are intricately interrelated. A common term for this is *embodiment*. Our thoughts and feelings are embodied. Educators tend to ignore this by prioritizing the mind over the body. Educational systems generally emphasize knowing over doing and feeling. Technology educators tend to reverse the order a bit and emphasize doing over feeling and knowing. Our theory of practice purposefully contradicts these priorities by demonstrating how doing, knowing, and caring are interrelated. In the models provided in this section, we nevertheless depict affective, cognitive, and psychomotor realms of experience as separate and divided. Similarly in the next section, our model depicts the ecological, ethical, political, and technical dimensions of technology as separate and divided. We do this for analytical purposes; the separations allow us to talk about the importance of each and reflect on the nature of learning. In practice, of course, our experience is unified and embodied. Teachers are challenged to think in wholes and unities while at the same time thinking in terms of fragments and divisions. With that said, then why designate an order for our theory of practice? Why say that caring and knowing derive from doing and the *disclosive* power of technology?

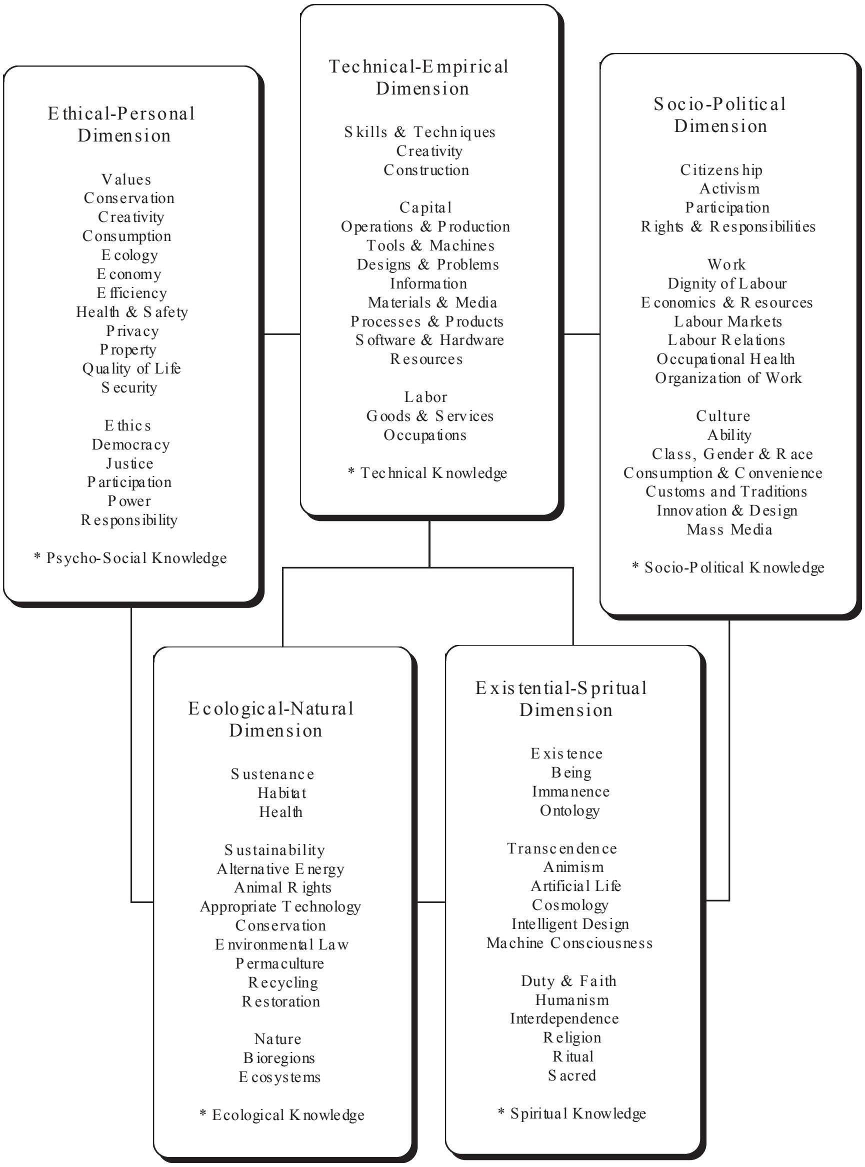
Practice Draws from the Disclosive Power of Technology

"We learn by doing if we reflect on what we have done"

~ John Dewey

What are the roles of technologies in our theory of practice? John Dewey, one of the great philosophers of the twentieth century, was extremely interested in the role of technologies in education and experience. Dewey was especially interested in the roles of creativity, materials, machines, and tools in the practices of education. According to Dewey, technologies have a "disclosive power" or a power to reveal the conditions of the world to individuals (Blacker, 1994, p. 309). Technologies disclose self-knowledge and feelings as well as the cultural and material conditions of subsistence, work, and home life. Rather than choosing technologies to develop a certain skill, teachers would choose technologies to disclose insights into the conditions of the world. With this idea of disclosive power, Dewey declared that "we learn by experience" and more specifically, "we learn by doing if we reflect on what we have done." As students worked with and studied certain technologies, and, with the help of the teacher, as these technologies disclosed the conditions and

Figure 3. Theory of practice in technology studies



workings of everyday life, students would develop what was once called "industrial intelligence." "Unless the mass of workers are to be blind cogs and pinions in the apparatus they employ," Dewey and his daughter reasoned, "they must have some understanding of the physical and social facts behind and ahead of the material and appliances which they are dealing" (Dewey & Dewey, 1915/1962, p. 178). Today, we call this technological literacy (see Chapter VII). If doing leads to knowing, what exactly should students be led to know (Figure 3)?

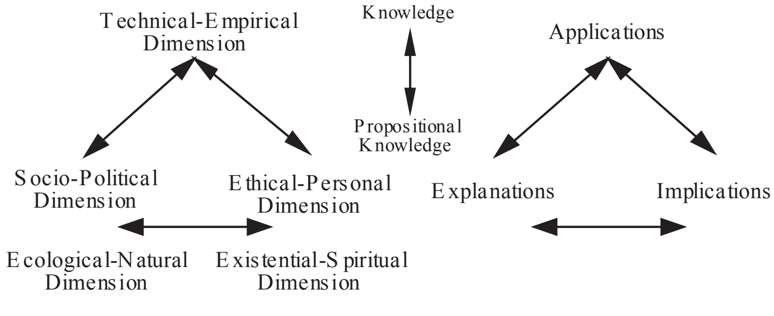
Of course, technologies do not automatically give up revelations concerning the conditions and workings of the world. Doing does not automatically lead to knowing. We have to reflect, and with the guidance of a teacher and other resources, we have to observe, examine, contemplate, and care about our doings in the world. We have to use disclosive analysis, as described in Chapter V. Education is supposed to be designed with this purpose in mind and heart. In technology studies, we specify the terms in a slightly more focused way than doing, feeling, and knowing. Since the subject is technology, we focus on the dimensions of technology that correspond to action, emotion, and cognition. For reasons that will be elaborated in this chapter, we take Dewey's precedence at face value. In our theory of practice, the technical-empirical dimension of technology discloses the ecological-natural, ethical-personal, existential-spiritual and socio-political dimensions of technology (Figure 3). Applications disclose implications and explanations. Learning about technology is cyclical, not linear. Practice that is stalled in one dimension is restricted and limited. Dewy gave us a starting point in the cycle.

Dewey defined an order for practice and teaching in technology. He gave a logical and psychological precedence to technology and skills, noting that doing precedes feeling and knowing in practice. He gave an order to the arts and crafts mantra of the head, heart, hand, and feet, or to action, emotion, and cognition. Through the notion of the disclosive power of technology, he gave an order to the technical-empirical, ecological-natural, ethical-personal, existential-spiritual and socio-political dimensions of technology. And there is an order to the question of applications, implications, and explanations (Figure 4). Pedagogical movement is explained in Figure 4.

In our theory of practice, we move from the problem of how things work to the problems of how things work for some but not others and who's in charge. We move from doing and feeling to knowing and changing the way things are—the head, heart, hand, and feet are represented and given direction.

This was analytical—Dewey realized that emotions can rise quite unexpectedly in

Figure 4. Precedence in technology studies



anticipation of the mere thought of doing things with technology. He realized that an individual should know something about a technology prior to using it. He realized that action, emotion, and cognition occur simultaneously in experience. The logical and psychological precedence given to doing was based on his observations of how people learn. He noted that individuals learn through cycles of experience. He criticized the schools for the inability to incorporate experience into everyday processes. "That we learn from experience," he said, "and from books and the sayings of others *only* as they are related to experience, are not mere phrases. But the school has been set apart, so isolated from the ordinary conditions of life, that the place where children are sent for discipline is the one place in the world where it is most difficult to get experience—the mother of all discipline worth the name" (Dewey, 1900, p. 31).

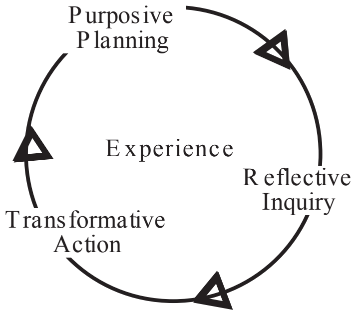
Dewey's Theory of Experience

It is not experience which is experienced, but nature—stones, plants, animals, diseases, health, temperature, electricity, and so on. Things interacting in certain ways *are* experience; they are what is experienced. Linked in certain other ways with another natural object—the human organs—they are *how* things are experienced as well. Experience thus reaches down into nature; it has depth. It also has breadth and to an indefinitely elastic extent. It stretches. That stretch constitutes inference. (Dewey, 1929/1952, pp. 4a-1)

Dewey asked the simple question, "what is an educative experience?" His investigations into this question from the 1910s through the 1930s have been fundamental to experiential education. Dewey noted that experience does *not* passively unfold through our interaction with the material and natural environment. Rather, experience is actively sought out through extrinsic motivations and intrinsic forces such as curiosity, hunger, and an urge for expression or freedom. Inquiry and expression, or sometimes coercion in everyday life, inspire *an* experience. Dewey argued that education was experience. Education, he said, "is that reconstruction or reorganization of experience which adds to the meaning of experience, and which increases ability to direct the course of subsequent experience" (1916, p. 89-90). For Dewey, everyday life or "lived experience" has a structure.

The structure of our experiences has three phases: purposive planning, reflective inquiry, and transformative action (Figure 5). The boundaries between these phases are indistinct, but can be analyzed separately. Purposive planning can be inspired by any endeavor, but personal meaningfulness is the primary inspiration. We actively plan for experience with a purpose in mind. Reflective inquiry consists of turning our purpose over in the mind and giving it serious and consecutive consideration. Through this process, we step back to abstract meaning or emotions and knowledge

Figure 5. Dewey's model of experience



from our actions. We check in with our head and heart to determine how things went—how we felt and what we learned. Reflective inquiry is a key for comprehending the significance of personal actions, and for illuminating everyday problems, values, and possibilities. Inquiry is the practice of discovering connections between something that we do and the consequences which result. Reflection is the acceptance of responsibility for our actions and the consequences of anticipated actions. In this way, the structure of experience is tied to a sense of responsibility, values, a search for meaning, and a concern for social consequence. Purposive planning and reflective inquiry transform action into experience. Transformative action means that we act on our intents and purposes. Transformative action also means that we are transformed and transform the environment in which we act. We are different than we were prior to having an experience. The entire cycle is the experience.

Dewey asserted that *not* everything had to be, nor could be, learned through experience. Dewey criticized educators for short sighted and naive interpretations of experience, and it was on this issue that much of the so-called experience-based or activity work of design and technology education is challenged. Doing is not, *automatically*, learning. If hands-on activity or experience is to be meaningful, it has to be purposefully planned, reflective, and transformative. Dewey argued that teachers should drop the pretense that by merely providing students with hands-on experiences they are educating their students. Most of it could be dismissed as busywork or what in business and industry are referred to as make-work situations.

Kolb's Theory of Experience

David Kolb (1984) expanded on Dewey's work and provided a model of experience that links experience to teaching. Like Dewey, Kolb acknowledged that we perceive the world through sensing and feeling. Our senses and feelings filter how we observe the world and the way we see reality. We also internalize what we perceive and make it our own. We internalize our experiences. From what we *perceive* or observe, we *conceive* or conceptualize. Our conceptions, or what we conceive, influence our perceptions, or what we perceive. From what we apprehend, we comprehend and vise versa, within a cycle. We move from the concrete to the abstract and back to the concrete through experience. We move from divergent to convergent action and back again. We assimilate and accommodate. We manipulate the world so that we can change and comprehend ourselves and the world. Experience is a cycle for Kolb, as it was for Dewey (see Preface, Chapter IV).

Some people prefer to perceive the world through concrete experience. These people perceive by sensing and feeling, and prefer to use intuition to solve the problems of a given task. Other people prefer abstract conceptualization. They like to think things through, analyze, and intellectualize. They function well in structured situations. Some people prefer to process new information by active experimentation. They like to roll up their sleeve and immerse themselves in the task. They look for practical ways of applying what they learn. They embrace risk-taking and are results oriented. Other people process through reflective observation. They like to watch and ponder the situation. They likely see tasks from several points of view. They value patience and judgment. Concrete experience, abstract conceptualization, active experimentation, and reflective observation are four general emphases, or learning styles as noted in Chapter IV.

Outdoor educators who deal with camping, climbing, boating, hiking, skiing, and the equipment of the outdoor adventure face the same challenges as technology educators. The temptation is to emphasize the action and marginalize emotion and cognition. There may be an emphasis on safety and its concomitant dispositions and knowledge, but the tendency is to restrict experience to action or activity. This is where theories of experience are essential to practice. Outdoor educators, like design and technology educators, are challenged to move their students toward responsibility, intimacy, caring, and compassion for, and knowledge of, the natural environment. Dispositions and knowledge never automatically derive from action. Teachers who work with experiential learning as a basic theory have to complete the cycle by moving their students to reflection and transformation to insure that desired dispositions and knowledge are the outcome. Action leads to emotion and knowledge if we reflect on what we have done. This may entail debriefing and other methods provided in Chapter IV.

Thus far, we have constructed our theory of practice through notions the head, heart, hand and feet, the disclosive power of technology, and cycles of experience. We generally dealt with the place of technologies in our theory of learning, but we have not directly dealt with action in a material world. In Dewey's and Kolb's theories of experience, the role of technologies, the physical setting, and the material world is unclear or under-theorized. When we act on the world the world acts on us. As we change the world, we change ourselves. These premises may seem basic, but they are extremely important in understanding practice in design and technology.

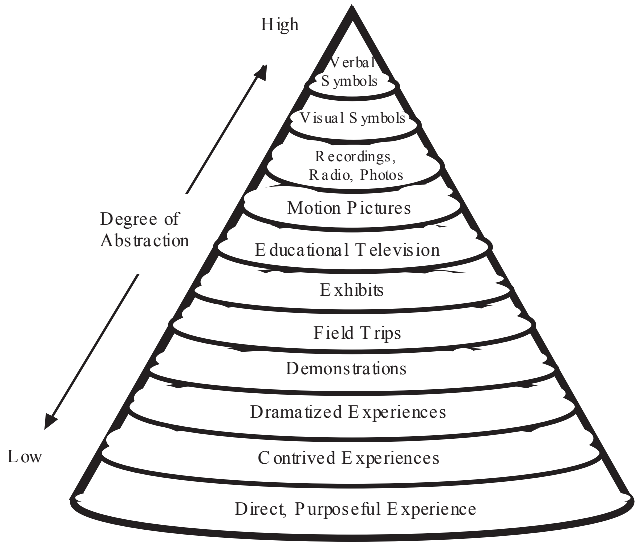
We have to return to the concept of embodiment and demonstrate how we embody the material world and how the material world embodies us. We have yet to fully re-materialize our theory of practice, which has critical implications for C&I in technology studies.

Dale's Cone of Experience

One step in re-materializing the cycles of experience is to consider the progression from concrete to abstract learning. In 1946, Edgar Dale introduced the Cone of Experience to demonstrate a progression from direct, first-hand experience to pictorial representation and on to purely abstract, symbolic expression (Figure 6). The Cone of Experience corresponds with three major modes of learning: enactive (direct experience), **iconic** (pictorial experience), and **symbolic** (highly abstract experience).

Enactive or direct experience involves practicing with objects (the student actually ties a knot to learn knot-tying). Iconic experience involves interpreting images and drawings (the student looks at drawings, pictures or films to learn to tie knots). Symbolic experience involves reading or hearing symbols (the student reads or hears the word "knot" and forms an image in the mind). Enactive experience involves concrete, immediate action and use of the senses and body. Iconic experience is once removed from the physical realm and limited to two or three senses. In sym-

Figure 8. Dale's Cone of Experience (Adapted from Dale, 1946)



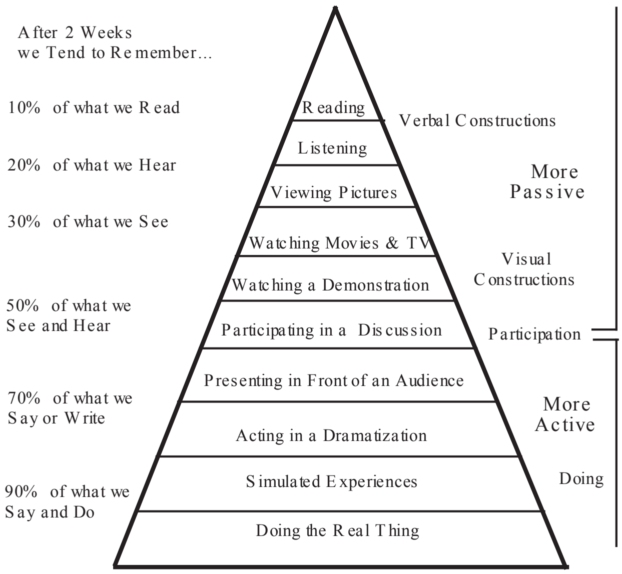
bolic experience, action is removed nearly altogether and the experience is limited to thoughts and ideas.

The Cone of Experience does not represent a literal progression from the concrete base to the abstract pinnacle. We do *not* literally progress through the cone's levels. The cone represents a range of experiences through which we learn, and various levels of the are fluid. Modes of experience are fluid, and learning often involves all three major modes at once. In technology studies, where experiences can be extremely enactive, iconic, *and* symbolic, we give priority to direct first-hand experience. Our richest sense impressions involving feelings and perceptions are formed as we explore the world. We call this lively, embodied participation our bedrock for learning. Through the five senses, or what Dale called the "unabridged experience of life," we generate a wealth of meaningful knowledge and feelings about ourselves and our world. This is not to say that direct experiences are more valuable than iconic or symbolic experiences. All three modes are equally important in learning technology. We give direct experience precedence to orient the trajectory of learning from the concrete towards the abstract; the process is incomplete until we follow through to abstraction and symbolic experience. Teachers are faced with the challenge of how to provide the most suitable combination of concrete and abstract experiences. Technology teachers tend to over-emphasize direct experiences over the abstraction necessary for learning about technology. This is the same as saying technology studies is restricted if we stall in the technical-empirical dimension of technology and fail to move our students into the ecological-natural, ethical-personal, existential-spiritual and socio-political dimensions. In order for students to develop meaningful knowledge, feelings, and skills, their direct experiences must be "associated with abstractions," as Dale noted. Language and expression are essential to skill acquisition.

Although no experience is fully passive, iconic and symbolic experiences are generally more passive than direct experiences (Figure 7). Watching chefs prepare a meal on television, however much our minds are actively engaged, is quite passive compared actually preparing a meal in a kitchen. Dale proposed that active and passive modes of participation can be contrasted by assigning a percentage of we tend to remember after two weeks after our experience. Although he never tested these percentages and they seem exaggerated, they serve as rules of thumb for teaching. Nonetheless, education involves a range of experiences, some of which are direct, some iconic, and others symbolic.

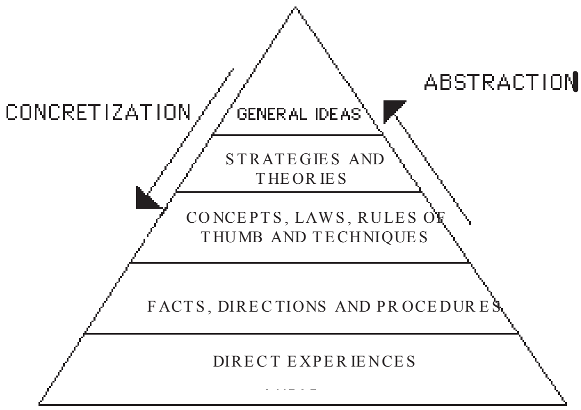
As explained in Chapter II, teachers have to move their students from direct experiences, procedures, and facts to concepts, laws and rules of thumb and eventually strategies and theories (Figure 8). The Cone of Experience invokes a bi-directional movement from the concrete to abstract and from the abstract to concrete. Our theory of practice in technology studies merely turns the cone into a cycle which involves the doing, feeling and knowing dimensions of experience, or the technical-empirical, ecological-natural, ethical-personal, existential-spiritual, and socio-political dimen-

Figure 7. Passive and active aspects of the cone of experience (Adapted from Dale, 1946)



sions of technology. Whereas Dewey and Kolb overlook objects and material culture in their theories, the Cone of Experience accounts for "things." However, Dale's theory suggests that objects and the material culture of technology are mere augmentations or media to be used in the learning process. To fully empower teachers with a theory of practice in technology studies, technologies and physical settings have to play a more active role in cognition, emotion, and action.

Figure 8. Simplified cone of experience



Modes of Learning with Technology

As indicated, there are three general modes of learning: enactive (direct experience), iconic (pictorial experience), and symbolic (abstract experience). Some theorists prefer to be more specific and refer to conditioned, imitative, trial and error, investigative or expansive learning as six possible modes of learning. Conditioning refers to learning by pre-design or control *via* a series of punishments and rewards. Imitation refers to learning tasks by observation or modeling. Trial and error refers to learning *via* a series of successful and unsuccessful trials and deliberations. Investigation refers to learning *via* a series of informed hypotheses and inquiries into problems. Expansive learning refers to the questioning of the validity of tasks and problems of a given context to the transformation of the context itself.

However, this is a different way of looking at learning than is typically the case. Each of these modes involves technology in some way, shape or form. However, in the way that the three general modes and five specific modes are defined and used, technologies are seen to merely augment or amplify the learning process. This is the use in Dale's cone of experience. This is the instrumental view of technology: technologies are instruments or tools to enhance the learning process. Of course, this grossly simplifies the activity of technologies in the learning process. This masks the power that technologies have to shape our actions, feelings, and thoughts. In order to interpret the role of technology in the learning process in a sophisticated way, we have to acknowledge the range of possible modes in which technology penetrates our being. There are six different possible modes of learning with technology:

1. **Tacit learning:** Technology operates in the background as infrastructure. Technology backgrounds and foregrounds the learning process. We are immersed in a world and always learning. We learn through observation, association, socialization, and immersion in established routines. We learn when we least expect we are learning.
2. **Augmented learning:** Technology augments, enhances, extends, or magnifies our senses. Technology augments the learning process. The world is given a boost through technology and made more decipherable or perceivable to our senses. The world is merely amplified, magnified, or clarified in the process of augmentation, somewhat like a prosthetic. This was McLuhan's notion of media.
3. **Mediated learning:** Technology mediates between our senses and the world. Technology mediates the learning process. The world is transferred to us and changed through some medium or intermediary (technology). We are once removed from reality, which is distorted or changed in the process of mediation. Our experiences and learning are mediated by some person (i.e., mother, teacher) and technology (i.e., book, internet, radio, television).

4. **Distributed learning:** Technology distributes our actions, feelings, and thoughts. Technology distributes the learning process. We are fragmented and made complete by metaphorically plugging into technologies (i.e., books, computers, tools). We project parts of ourselves into and onto our technologies (More or less the same as mediated learning).
5. **Automated learning:** Technology models, automates, and simulates our senses and the world. Technology automates or simulates the learning process. The world is imperfectly modeled and completely changed for our perception. The lines between the artificial and real are blurred.
6. **Cyborgenic learning:** Technology is embodied and literally a part of us. We embody technology, technology embodies us. We are a hybrid of human and technology, or cyborg. As cyborgs, we program and are programmed in a learning process. Beyond projection and plugging into the circuit, we are in the circuit and the circuit is within us.

In each of these six *possible* modes, we are in some way dependent on or interdependent of technology. The degrees of distance from our technologies change across the six modes. If it were only so simple that we could pick the mode of learning that we preferred, the problem of embodiment and freedom would be easily solved. The fact is that we are involved with our technologies in all six of these modes—at once. If we are to understand how we learn with and about technology, we have to account for technology in the learning process. We cannot merely say that technology is instrumental to cognition or that technology merely augments the senses. We know that technology operates on much deeper levels that implicate our agency and freedom.

Agency, Embodiment, Technology, and Determinism

Are we free to use technology however, we want or are we constrained by the technologies we use? Do our designs and technologies respond with fidelity to our intentions and will or do our intentions often go awry? Do we put a part of ourselves into our technologies? At the same time, do our technologies contain a part of us? Are we compelled and destined to follow the paths and passageways laid out by our technologies? These questions underscore four major problems in understanding and theorizing our relationships with our technologies: agency, intentionality, embodiment, and determinism. What degrees of freedom do humans and their technologies have? What are the options in our deployment of technologies, their organization, and use? Agency refers to the degrees of freedom for either humans or technologies to act on desires, needs, and wants. Do we or our technologies act or react? Intentionality refers to the degrees of intention or will that are realized in either our actions or within the actions and designs of our technologies. Are technologies neutral or do they embody certain intentions? Embodiment refers to the degrees of which we are part technology and technology is part us. Determinism refers to the degrees in which we are determined by our technologies to act and will in limited ways. Our fundamental premise is that material conditions and things matter.

In Chapter III, we asked whether technologies can emote and act. We asked whether humans invest technologies with their desires, interests, and values. We noted that individually, particular technologies may determine what we do on a small scale. But collectively, technologies gather more influence over our lives. Most theorists interested in our actions and thoughts readily accept that we invest technologies with our desires, interests, and values. Technology embodies us. Langdon Winner aptly summarized this in saying "artifacts have politics." Just as we delegate certain tasks to each other or our subordinates, we delegate certain tasks to our technologies. When we delegate tasks, we also invest desires, interests and values, or politics, into technologies. Think of a stove. When we touched the hot stove and nearly burned our fingers when we were young, the stove suddenly took on awesome powers. After nearly getting burned, we invested the stove with all sorts of powers to be something fierce to be reckoned with. We need not have been burned or touched the stove to learn. We could have learned the powers of the stove through our mother or father. But from then on, the stove had powers. We could say this is a simple stimulus response situation. The hot stove or mother's warning caused us to act with fear and alarm. The stove caused us to approach it with caution from then on. We could say we merely projected the powers onto the stove, but the result would be the same. This simple behavioral example merely demonstrates that technologies can embody whatever we project into them. It demonstrates that technologies can direct our everyday actions.

Rules and procedures often emerge from material conditions to guide and limit our responses. A prime example of determinism and conditioning is the flow of vehicular and pedestrian traffic. In North America, we learn early on to pass people as we walk in hallways, shopping malls and on sidewalks left shoulder to left shoulder, or on the right hand side of the pathway. The custom issues from vehicular traffic. Our material culture of roads and traffic determines our behavior in malls, offices, and schools. In Australia, you will find yourself walking right shoulder to right shoulder on sidewalks. Vehicular traffic, of course, flows right side to right side, the opposite of North American traffic. We embody the traffic system.

When we talk about technologies however, we are not just talking about objects. Technology has four different manifestations, as identified by the philosopher Carl Mitcham (1994). The most concrete manifestations of technology are in the form of artifacts or objects. This includes simple components and architecture as well as complex engineering projects, machines and electronic equipment. Mitcham outlined different types of tools and machines which typify technology as object or artifact (Table 1).

The second manifestation is activity or process. This includes the process of smelting iron as well as activities such as designing, engineering, maintaining or building. Technology also takes the form of knowledge. Technology may be in the form of procedures for networking computers or the formulas in civil engineering for testing load bearing capacity. The last manifestation of technology, volition or will, is the most abstract. It is also the most important to grasp. Technology as volition refers to technological determinism. Figure 6.9 captures all four manifestations of technology (Mitcham, 1994, p. 160).

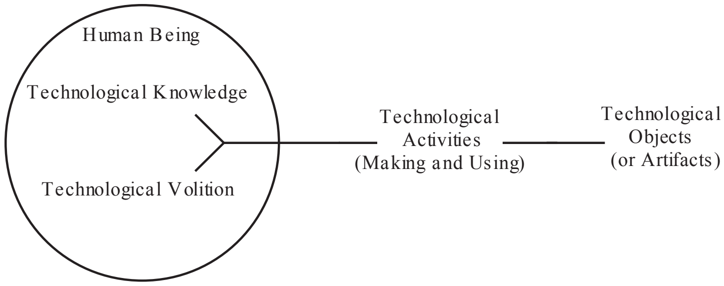
We exert a certain amount of energy and determination into our technological activities. Our compulsions or inclinations toward technology are directed by our technologies as well as our will. We are compelled, inclined, or determined to act in certain ways.

In all learning theories, there are questions of agency, intentionality, embodiment, and determinism. Marx argued that economics and technology largely determine the way that knowledge is constructed and acted on, or the way we behave. Freud argued that the unconscious Id and the subconscious Super-Ego together largely determine the way that the conscious Ego constructs knowledge and guides behavior. Constructivists suggest that knowledge is much less determined than Marx and Freud argue. In other words, we construct knowledge pretty much as we please. Activity theorists and theorists of distributed cognition help us rethink determinism and free-agency or self-actualization. Agency and intentions are present, but mediated and somewhat or sometimes determined. Learning theories also have to take Mitcham's four manifestations of technology into account in some way, shape or form. The following five sections deal with different learning theories that take technology into account, some more adequately than others. In other subjects, it may be all well and good to merely consider technology to be instrumental in augmented

Table 1. Organization of tools and machines (adapted from Mitcham, 1994)

	Analytic elements	
Kinds of tools	immediate source of energy (matter)	immediate source of guidance (form)
Hand tools	Individual human beings	Individual human beings
Premodern machines	Groups of humans or animals	Individual human beings
Modern machines	Inanimate nature (wind or water) and technologically controlled nature (steam engine)	Individual human beings or groups of humans assisted by mechanical controls
Power tools	Technologically controlled and abstracted nature (electricity)	Individual human beings and mechanical or electrical controls
Cybernetic devices	Technologically controlled and abstracted nature (electricity)	Electronic controls

Figure 9. Manifestations of technology (Adapted from Mitcham, 1994)



learning. Nevertheless, for the subject of technology, more sophisticated theories of technology are necessary.

Learning Theories

Just as the development of cultures over time cannot be accounted for without taking technologies into account, learning theorists during the 1920s and 1930s noted that human development from children to adults cannot be accounted for merely by biology or growth. Technologies are essential in any account of cultural or human development. In fact, psychologists prior to the 1920s suggested that human development repeats the patterns of cultural development. This genetic development model held that humans, like cultures, begin in the rather "primitive" stage of childhood and advance through progressively sophisticated stages. People and cultures develop through progressively sophisticated tool use. This was recapitulation theory. Ontogeny (individual development) recapitulates phylogeny (species development), theorists once said. However crude this developmental theory of progress now seems, the important point was that it acknowledged the centrality of technologies to both cultural and human development. Theorists of industrial arts, such as Lois Mossman (1938, p. 60) combined recapitulation theory with the disclosive power of technology. "Genuine social appreciation is furthered if one understands the simple hand processes and the steps in the evolution to the complex machinery processes," she observed. Teaching how to weave a simple rug "provides a bit of detailed experience in a process—a detail that is fundamental in appreciating the weaving industry of the world of all time." The simple act of weaving could disclose the craft basis of the complex machinery of the modern weaving industry.

Learning theories have generally focused on how individuals organize their behavior, but at the neglect of material conditions and technology. Learning theories generally grant near total freedom to humans to act and will, neglecting the powers that technologies possess to act on humans. Most current learning theories are reactions to behaviorism, which reduced human freedom and granted determinant forces to culture and the environment. In many ways, the issue of freedom and determinism is analogous to the old nature-nurture debate. Does the environment make the person and the personality, or is it biology? If the answer is both, then when is one more influential than the other? Nature and culture must somehow work together. This of course, is a concession that technologies do play an active role in everyday affairs. This notion of balanced interplay is a challenge to learning theories. Learning theories must recognize the interplay between agency, intentionality, embodiment, and determinism or between motivated individuals and groups, material culture and material forces. In the learning process and theories of practice, we have to account for agency, intentionality, embodiment, and determinism. This is the main criterion for technology educators to judge learning theories. Our fundamental premise is that material conditions and things matter.

Behaviorism

Behaviorism and neo-behaviorism are primarily associated with the work of psychologist B. F. Skinner. However, behaviorism began in the early 1900s and was elaborated on during the 1920s by the American psychologist John Watson and Russian psychologist Ivan Pavlov. Watson defined behaviorism as the prediction and control of behavior. He basically responded to dominant learning theory of his times, which was based on biology and the notion that students' abilities were limited by heredity or genetic inheritance. Against this, Watson claimed that people (e.g., abilities, personalities, etc.) were made not born. We are conditioned through the control of environmental stimuli and systems of punishments and rewards, said the behaviorists such as Watson. Through repetitive uses of punishments and rewards, we can be conditioned to act consistently over time. Behaviorists observed that learning could not be accounted for without accounting for technologies in the process. Behaviorists theorized that technologies establish the conditions and more or less determine the results of the learning process. Learners are not passive vessels; nor is the environment passive. Rather, learners actively respond to stimuli in their environment as an adaptive strategy and the environment acts on the learners by stimulating select responses. As Skinner (1953) wrote, "the environment determines the individual even when s/he alters the environment" (p. 448). Behaviorism reiterates Marx's observation that as we work in and transform the world we also transform ourselves.

Skinner (1961) turned these premises into a learning theory of radical behaviorism. He argued that behavior should be manipulated and produced by design, or according to a plan simply by arranging conditions and technologies. "With the help of devices and associated techniques," he wrote, "we change the behavior of an organism in various ways, with considerable precision. But note that the organism changes our behavior in quite as precise a fashion" (p. 543). For this reason, he looked at educational, economic, religious, and therapeutic institutions as "behavioral technologies." They are in the business of producing and shaping particular behaviors. He noted that teachers most often produced certain behaviors by merely maintaining a system of punishments rather than by dishing out punishments. Skinner advocated a deliberate manipulation of conditions and technologies to bring about desired behaviors. In behaviorism, technologies are essential to the learning process. Technologies are both active and malleable, responsive to the task of controlling and shaping behavior. As Skinner and behaviorists asked, how conditioned are we by our technologies? The problem is not if we are conditioned and determined, but how.

Piaget and Cognitive Development

In the 1930s, Jean Piaget set out to study the way that children and adolescents interact with their environment. Basing his studies on the educational environment designed by Maria Montessori, Piaget theorized that technologies were instrumental to development. He did not study technologies, *per se*. Whereas Skinner was interested in behavioral control, Piaget was interested in the way technologies impinge on cognition and intellectual development. He observed and tested hundreds of children to chart their cognitive development through their encounters with language and manipulative technologies. In fact, Piaget established a cognitive development theory based on abilities to manipulate technologies and technological concepts. He identified four major stages in cognitive development (Piaget, 1952, 1972): sensorimotor stage (infancy); pre-operational stage (toddler and early childhood, 2-7 years); concrete operational stage (elementary and early adolescence, 8-12 years); and the formal operational stage (adolescence and adulthood. Basically, Piaget theorized a cognitive developmental process from infancy through adulthood.

The key to what Piaget observed is how children and adolescents learn about their everyday world. Although not entirely novel, Piaget observed that knowledge about the world is not simply transmitted from teacher to students. He documented student after student actively constructing new knowledge by adapting it to what they already knew. They accommodate new experiences by assimilating these into their existing knowledge, or what Piaget called schemata. Children and adolescents learn about the world by actively manipulating technologies in the world. Their development of language and symbolic thought is dependent on their manipulations of their technological world. While not always entirely accurate (e.g., taller means more), they build theories out of things. Basically, Piaget found that doing with things and images (concrete activity) makes symbols (abstract thought). Nevertheless, Piaget did not adequately theorize the role of the technologies in learning. Technologies were merely instrumental and pliable, or easily manipulated. Nor did he address the social nature of learning.

Constructivism

Constructivism is primarily based on the work of Montessori and Piaget. As Piaget found, we actively *construct* knowledge as an adaptive response to our environment and developmental growth. Learners are *not* passive, receptive vessels. Rather, learners are active participants in the construction of knowledge. The lesson here is that students do *not* learn exactly what we want them to learn; they reconstruct what we demonstrate, discuss and adapt it to fit their everyday life (Phillips, 1995; von Glaserfeld, 1995).

Within constructivism are two core premises. The first is that students actively construct meaning from what they learn, in ways that are consonant with and lend coherence to their experience. The second is that cognition is functional and adaptive, and allows us to cope with the world. This premise should not be new for technology teachers (see behaviorism). The meanings students derive from school or experience are personal. This knowledge is the product of complex intra- and intercommunications organized by the social roles the students consciously adopt for particular tasks. The child or adolescent takes the social role of student and develops knowledge that is characteristically student-centered (i.e., adaptive, dependent on authority, tentative). Knowledge in constructivism is an adaptation and a function of our personal history. What students come to know will likely be different from what the teacher intended. Teachers ought to pay attention to their students' language to understand what they learn, how well it is understood and the process of cognition. Learning actually requires self-regulation and the building of concepts through articulation of thought, reflection and abstraction.

To understand students' thinking, Piaget suggested that we look at the world through their eyes. Attention shifts from a teacher's abstracted and pre-processed world to the students' minds. Students' thinking and prior understandings must be taken seriously in the design and implementation of instruction. A teacher's knowledge about teaching and the thinking of her or his students evolves simultaneously with changes in the students' knowledge. Among the most important insights from constructivism is the issue of paying attention to students' language and their interaction with each other. The unit of focus is the individual. The emphasis is on the individual, active mind. In effect, the social nature of learning has been under-theorized in constructivism (Lewis, Petrina, & Hill, 1998).

Situated Cognition

Situated Cognition (SitCog) takes Piaget and constructivism with a grain of salt and is primarily based on the work of Russian psychologist Lev Vygotsky (1986) from the 1930s. Vygotsky's theory of cognition is founded on three principles:

1. Learning is a social activity and is mediated by the student's social environment.
2. Learning is mediated by the student's physical environment and the tools that he or she has at her or his disposal.
3. Learning takes place within a "zone of proximal development."

The zone of proximal development is the realm of the "almost understood," as opposed to the realms of the well understood and the completely unimagined. This concept is cited by theorists as the foundation of "scaffolding." Educational activities built around scaffolding attempt to encourage learners to build from concepts that are well understood to concepts that are almost understood. Vygotsky observed that learning is thoroughly social and that we learn when we are active. When we act however, we are *situated* in what Jean Lave and Etienne Wenger (1991) call a "community of practice" (p. 56, 98).

Lave, Wenger and other cultural theorists such as Sylvia Scribner (1985), built on Vygotsky's work and established situated cognition during the mid 1980s. They noted that cognition is distributed across time and across the individuals in our community—cognition is shared. Individuals enter into a community of practice (e.g., family, office, job site) by learning the language. The lesson in SitCog is that social arrangements are extremely important. SitCog theorists argue that constructivists under-theorize this extremely important point: learning is social. In a SitCog classroom, teachers model how success is established within the community. The technologies of these social arrangements are quite important.

Educational implications of situated cognition include an emphasis on the social and cultural *conditions* of learning, and on language. Teaching begins with students' conceptual understandings and relies on language as an entrance into a social system of expertise and acceptable performance. In SitCog, language is the single most important tool in knowledge construction. Problems are not solved *by* individuals, but *within* communities, through which students participate. The question is how to arrange complex, social environments. The constructivist question of "what is going on in a student's mind?" is extended to a SitCog "what kinds of social arrangements provide the best context for learning?" Hence, what is going on in the teacher's mind and the social relations between students and teachers are crucial. The intent of education in situated cognition is to recognize and nurture a thoroughly social environment through activity and discussion. Routine skills and knowledge for individuals are constructed in relation to the success of all participants in the community. Teachers, as authorities in the community, must *demonstrate* the means of success in this community of practice.

A spin-off from SitCog is enactivism, which expands Bruner's "enactive experience" and is derived from Maturana and Varela's *Tree of Knowledge*. In enactivism, cognition is ecological and nested in "complex webs of experience" (Davis & Sumara, 1997, p. 115). Enactivism underlines the importance of recognizing that cognition is nested. Individuals are nested in communities and environments which are nested in societies and regions which are nested in nations and continents which are nested in races and hemispheres nested in a planet and son on. SitCog and enactivism are theories of the ecological, seamless interconnections between psyche, culture and nature. These theories allow for complex understandings of learning, where cognition is neither fully personal nor environmental, but *situated* in activity of individuals and their natural and cultural environment. Although SitCog and enactivism appropriately recognize the social over the individual in cognition, neither adequately account for technologies in the process. They address our practice of thinking through others but undertheorize our practice of thinking through things (Davis, Sumara, & Kiernen, 1996).

Constructionism

Long before the learning theory of constructivism was popularized in the 1980s, another theory of constructivism was developed during the 1920s. In Germany, Holland, and Russia following the October 1917 revolution, constructivism was developed as an integration of art, architecture, engineering and design. Constructivism was a theory of practice for a new kind of technologist who would design new forms for the modern world. The premise of constructivism was that through the systematic study of the organic and geometric form and physical nature of the material world, a new environment for social change could be constructed. Literally, constructivism referred to the activity of building, designing and constructing. The artist-engineer of constructivism was literally to construct artifacts and buildings that would teach the value of community, as simple forms without deceit and motifs. Maholy-Nagy (1922/1998), a principal architect of the Bauhaus school of design, expressed the premise this way: The "reality of our century is technology—the invention, construction and maintenance of the machine. To be a user of machines is to be of the spirit of this century." The goal for students was the general study of technology, as opposed to specialized minutiae. "As soon as creating an object becomes a specialty and work becomes a trade," he wrote when he resigned from the Bauhaus in 1928, "the process of education loses all vitality … I can no longer keep up with the trade specialization in the workshops… The spirit of constructivism for which I and others gave all we had—and gave it gladly—has been replaced by a tendency towards application" (quoted in Naylor, 1985, p. 166).

In the 1960s and 1970s, Seymour Papert (1980) managed to merge the constructivism of Piaget with the literal notion of constructivism that referred to constructing and building. Papert called his theory constructionism to emphasize the doing and making aspect. Like his mentor Piaget, Papert observed that children do not get ideas, they make ideas. But he also noticed that students are likely to make new ideas when actively involved in designing and making an artifact—a robot, poster or computer program. Papert and his MIT Media Lab colleagues, such as Sherry Turkle, developed an interface between Apple IIs and a bunch of LEGO compatible motors, creating robots that could be programmed to manipulate LEGO building block sets. In their theory of constructionism, the Media Lab integrated motor skill manipulation with cognitive manipulation, building, and design, with computers. Papert began to theorize exactly what technology educators did not theorize: the role of technologies in cognition and learning.

Papert took Piaget to his logical conclusion: If cognition is dependent on the manipulation of the world, then why not give students things to design and manipulate in school? The premise is that when students construct things in the world they simultaneously construct knowledge and theories in their mind. As they construct things in their mind, they reconstruct the world. Although generally ignored by technology educators and learning theorists alike, constructionism offered a key piece to the inadequacies of learning theory to that point. Technologies are essential to learning, not merely essential to learning about technology. This echoed an undercurrent in education since at least the 19th century.

In the 1830s, the German educator Friedrich Froebel designed a series of wooden blocks and geometric shapes intended to program the play of young students. The "Froebel gifts," as they were called, were initially merely intended to facilitate the intellectual development of children. The blocks, like the erector sets of the 1910s, actually programmed children into thinking geometrically and spatially. In the early 1900s, Maria Montessori combined Froebel's gifts with her notion of a multi-sensory environment to develop an entire educational theory. Anticipating Piaget, she theorized that manipulatives were essential to cognitive development. There was a moral side as well. She observed that the environment and manipulatives were essential to the development of responsibility in her students. But it was not just any environment and manipulatives. She designed manipulatives that programmed and stimulated intellectual thought. She designed environments that structured the independence of her students. The important change from Montessori to Piaget to Papert was that Papert recognized that students need to design and construct, not merely manipulate, artifacts and their environment. But despite Papert's interest in constructionism, neither he nor his MIT colleagues adequately accounted for technologies or social interaction. Technologies, or manipulatives, were merely instrumental to cognitive development.

Activity Theory

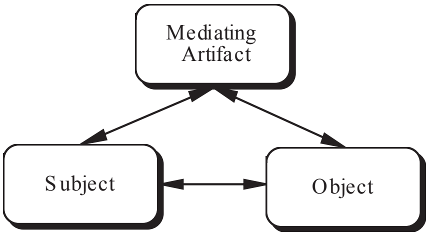
Labor is a process going on between man [sic] and nature, a process by which man, through his own activity, initiates, regulates, and controls the material reactions between himself and nature…. By thus acting on the external world and changing it, he at the same time changes his own nature. (Karl Marx, 1977, Vol.I, p. 283)

The key to understanding the role of technologies in learning is Marx's assertion that as we work in and transform the world, we also transform ourselves. Marx was most interested in how industrial work and the proliferation of material goods acted on human nature. He theorized that humans, individually, and human nature, collectively, were changed under the ever-expanding reaches of capitalism and commodities. He argued that qualitatively different technologies produce qualitatively different people. In other words, the technologies prior to the 1750s were qualitatively different than those of the 1800s, and in effect, so were the people of the urban centers. Marx theorized the relations between humans and technologies by reasoning that economics and technologies generally determine human behavior and nature. Material culture and tools affect the entire life and nature of individuals.

Working from Marx's fundamental observations, Vygotsky (1986) noted that individuals never directly react to their environment. Nor are they ever removed from their environment. He took Marx's observation that the unit of analysis for understanding people was labor, activity or practice, rather than merely their heads. The key to learning theory is activity. According to Vygotsky, the relation between the human and the environment is mediated by cultural artifacts (Figure 6, 10). The basic types of these artifacts are signs (language) and tools. Through education and other forms of socialization, individuals internalize the means of culture by participating in common activities with other humans. They internalize language, theories and norms and modes of behavior as well as how to use and adjust to technical artifacts. Thus cognition and consciousness do not exist inside the head of the individual but in the interaction— realized through material activity— between the individual and practice or labor of humankind. Activity is also socially mediated: cognition, consciousness, and meaning are always formed in joint, collective activity (Engestrom, 1999).

Vygotsky and his colleagues, Leont'ev and Luria, created a theory to account for activity. Human activity, they observed, was nearly always artifact-mediated and object-oriented. Humans rarely act on their environment merely with inborn instincts and reflexes. The relationship between humans and objects of their environment is nearly always mediated by cultural artifacts (e.g., knowledge, language, symbols, tools). This was a breakthrough. Technologies ceased to be just raw material for cognitive development, or augmented learning. Activity or learning is always situated within an *activity system* (Figure 11). An activity is undertaken by a human agent

Figure 10. Model of mediated activity (Adapted from Engestrom, 1999)



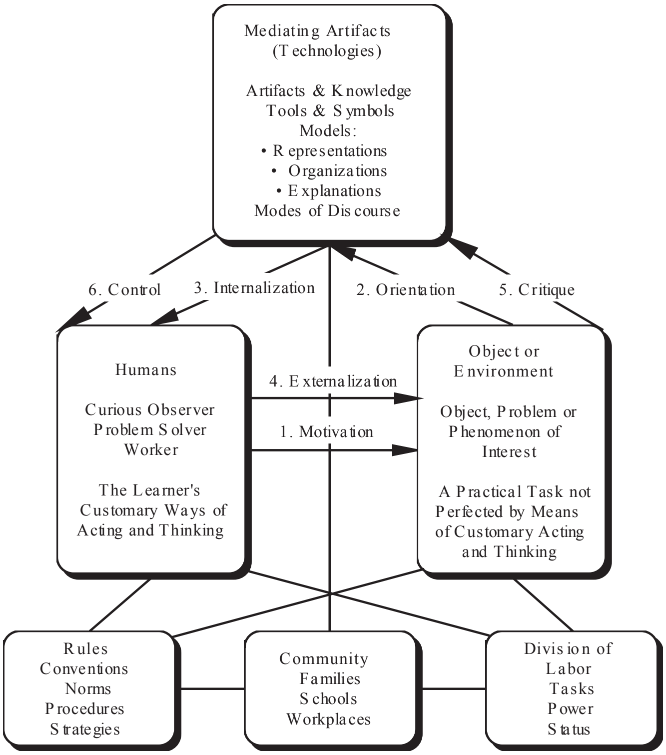
(subject) who is motivated toward a task (object), and mediated by tools (artifacts). The activity is constrained by the mediating artifact as well as cultural factors including conventions (rules), social groups (community), and social relations (division of labor) within the context. Learning is mediated by technologies and at the same time mediated socially. As Vygotsky and Luria (1994, p. 116) reasoned, "the road from object to child and child to object lies through another person." We act on the environment through social means, through people surrounding us in the form of rules, communities and a division of labor. Hence, we do not act individually. Individual activity is not divorced from collective activity (Engestrom, 1999).

Activity theory, as suggested in the model of an activity system, accounts for the range of technologies that Mitcham identified (activity, artifact, knowledge, and volition). At times we are free to act with intention or will on our environment. However, as Leont'ev noted, we are also constrained. There are times when our actions are automatic and not of our own free will. There are other times when we are directed either by our mediating artifacts or by the cultural rules, communities, or division of labor which we embody. This is a point that is easy to overlook. Activity theory also accounts for consequences and results that are not intended. Consequences can be quite other than those intended. Intentions and objectives can be distorted by mediating artifacts, rules or divisions of labor. In other words, there are always forces acting in and on us as we act in and on our environment.

Distributed Cognition

Some theorists expanded activity theory and situated cognition to distributed cognition, to emphasize that cognition is *distributed* across people *and* things. We do not think outside our social group *or* our technologies. Cognition is distributed across community, environment, *and* artifacts, rather than centered in the individual. Somewhat like behaviorism, distributed cognition suggests an active role for technologies in the learning process. Ed Hutchins (1995), the primary theorist of distributed cognition, defines learning as "adaptive reorganization in a complex

Figure 11. Model of an Activity System (Engestrom, 1999)



system" (p. 289). Learning, or adaptive reorganization, involves the coordination of resources that are internal to individuals (memory, attention, skill) *as well as* those that are external (artifacts, objects, environment). Learners are not isolated. Instead, we are part of a system—"a system of person-in-interaction-with-technology" (p. 155). "Distributed cognition does not posit a gulf between 'cognitive' process and an 'external' world, so it does not attempt to show how such a gulf can be bridged. Cognitive processes extend across the traditional boundaries as various kinds of coordination are established and maintained between 'internal' and 'external' resources" (Hollan, Hutchins, & Kirsh, 2000, p. 193).

Whereas activity theory places technologies *between* the subject and the object or intent of an activity, distributed cognition places technologies *with* the subject in the coordination of an activity. Cognitive abilities are *not* augmented or amplified. We delegate cognitive and physical tasks to technologies while these technologies transform the tasks for us. In this way, we offload tasks to technologies while they constrain our behavior at the same time. Constructivism reminds teachers to pay attention to language, SitCog reminds us to attend to social conditions, activity theory to culture, and distributed cognition to workflow. If we want to take advantage of what we know about distributed cognition, we have to help our students understand their place in human-technology interaction. We have to teach them how to coordinate their activity and behavior within complex systems.

Activity theory and distributed cognition turned our attention to activity, practice, and systems, precisely the concerns of technology studies. These learning theories validate our theory of practice explained in the first two sections of this chapter. We absolutely have to embrace learning theories that take technology as a serious subject. Anything less invalidates our existence and the need to study technology in schools. If technology is dismissed or relegated to an incidental role in the learning process *via* a learning theory, then there is nothing in the theory to suggest that we have to study technology. We study technology *not* because it is a force to reckon with or instrumental to skills, but because technology is *central* to cognition and action. Where do we begin? We begin with technologies. We begin with what is mediating our encounters with our environment, goals and problems. We begin with our subject of study: technology.

Projects

Many so-called projects are of such short time span and entered upon for such casual reasons, that extension of acquaintance with facts and principles is at a minimum. In short, they are too trivial to be educative (Dewey, 1931/1964, p. 422-423).

What role do projects play in the process of learning with and about technology? For the most part, projects in technology studies refer to things to be designed, imaged or built. Projects are generally organized by a step by step instructional process that typically involves a toggling between teacher demonstrations and student practice. At times, especially in the upper levels of the schools, projects take on a more independent, self-directed form. In this independent form, students generally carry out the demands of design, imaging, or construction virtually unassisted, using the teacher as a facilitator and resource. A logic is employed to suggest that the more complex or independent the project, the more complex the learning. However, as Dewey noticed in the early 1930s, the technical complexity of projects does not dictate their educational value. In fact, Dewey noted that there was a side of projects that was ignored by teachers. He reminded us that the project is not merely the thing. In addition to a thing, projects are a method for disclosing self-knowledge and feelings as well as the cultural and material conditions of subsistence, work, and home life. Projects then, have two meanings. One is the notion of the project as a product or a challenge to be taken on. The other is the notion that the project is a method for disclosing meaning from everyday life. The methodology of projects is provided in Chapter IX. If we accept that projects are a method for disclosing a range of content, then we can treat projects the way we treat technology in our theory of practice. We use projects and technology for their power to disclose content (Chapter IX). How do we do this?

Following the revolution of 1917, the Russians championed the project method precisely for this disclosive power. The entire school system of the USSR was oriented toward projects in the 1920s for their capacity to disclose the workings of socialist industry and society and ultimately to transform the lives of the students (Knoll, 1997). Projects, rather than subjects, were the principle means of organizing curriculum. Projects related to surveys of illiteracy, mortality, or illness disclosed the applications of math to everyday life. Projects in agriculture disclosed the applications of chemistry to the fertility of soil, fertilizers, and pesticides. Housing and transportation projects disclosed the applications of physics. Other projects disclosed the realities of labor and technology. This is the climate in which Vygotsky began to study the importance of language and the disclosive power of artifacts in the process of learning.

In our theory of practice, projects and technologies are used to disclose and provoke feelings and knowledge. Remember, when we speak of technologies we are referring to objects, activities, knowledge and volition. Technologies disclose self-knowledge and feelings as well as the cultural and material conditions of subsistence, work, and home life. It is relatively easy to say this is the case. How can technology teachers can draw knowledge and feelings from technologies? How does doing lead to knowing? Doing leads to knowing through projects and our methods of disclosive analysis outlined in Chapters V and IX.

Projection and Reflective Practice

In Chapters II and III, we addressed the emotional, cognitive, and sensorimotor dimensions of learning. In this chapter, we integrated action, cognition, and emotion into learning theory. The challenge of contemporary learning theory is accounting for technology, or for technological artifacts, activities, knowledge, and volition. Learning theories have to account for big "T" Technology as well as all the small "t" technologies that we confront on a daily basis. A theory of practice in technology studies was elucidated to provide a framework for understanding the role that materials and technologies play in action, cognition, and emotion. Dewey and Kolb's theories of experience were described and tied to our mission to educate the head, hand, heart and feet about, through and for technology. Dale's cone of experience helped us to understand the roles of technologies in enactive, iconic, and enactive modes of learning. We refined the of modes of learning with technology by distinguishing among tacit, augmented, mediated, automated, distributed and cyborgenic modes of learning with technology. As Mitcham reminds us, technology is not just objects, but also activities, knowledge and volition or determinism. Theories of learning have to account for technology on all four of these levels. The learning theories that account for technology in some way, such as behaviorism, constructivism, situated cognition, and constructionism provide a good backdrop with which to theorize practice in technology studies. Distributed cognition and activity theory are the most complex of learning theories when it comes to accounting for technology. This was an extremely theoretical chapter, and it is important to recognize that theory is power.

If in our theory of practice technologies disclose knowledge about the conditions of life, then *how* does this happen? We use the disclosive power of technologies and our methods of disclosive analysis as the best means we have at our disposal. The previous chapter dealt with disclosive analysis methods. In the next chapter, we will address the various ways with which we justify the study of technology in the schools. If doing leads to knowing, then *what* exactly is the content to be learned? The primary justification is the content of technology, disclosed through methods such as disclosive analysis and projects.

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Chapter VII

Justifying Technology Studies

Introduction

Why should we teach technology in the schools? What is the reason for accommodating technology in the school curriculum? Why should we have to justify existence? Are the public schools an appropriate institution for developing economic human resources? Should students be taught to think critically about technology? Is the technology laboratory or workshop the place in the school where the students can "put it all together"? Will technology studies lose its identity in an alignment with math and science? Should technology studies serve to remedy long-standing inequities in technology? Should technology studies be aligned with ecology and sustainability? Is the future engineering education? These are some of the primary questions that impinge on the direction of technology studies in the schools. Throughout the 20th century, technology studies expended an inordinate amount of energy justifying itself. At times, it seemed as though this subject was trying to be all things to all people. In this chapter, we make the case that there is one, and only one, persuasive justification for the inclusion of technology studies in the schools. That justification is the content of technology. No one will buy all the things to all interest groups' justification anymore.

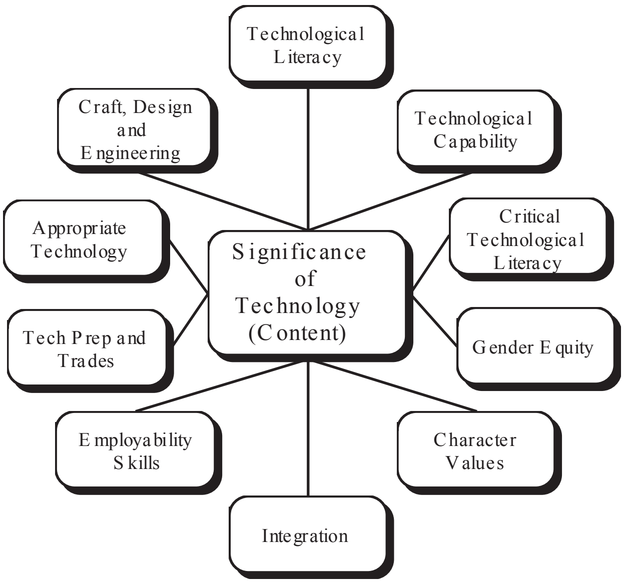
No longer does technology studies have to shift its identity from situation to situation, appearing avocational in one place, vocational in another, and academic in a third.

No more does technology studies have to take a subservient role to other subjects by appearing in integrationist garb, serving to provide applications or relevance to apparently irrelevant endeavors in the schools. No more does technology studies have to be cobbled together from the remnants of the past. The days of doing summersaults and cartwheels or drawing sophisticated flow charts to demonstrate why technology should be included in the K-12 curriculum are over. Activities, projects, and the orientation of practice derive from, and lead toward, the progressive understanding of technology as a social force and social product. They derive from and lead toward established content of technology.

Technology studies is *not* justified by the mere fact that we use technology; nor is it defined by an appeal to technical skills. Technology studies is justified by a theory of practice, about, through and for technology as explained in Chapter VI, and by the all-important imperative of understanding and directing technology in all of its manifestations.

While the primary justification for technology studies in the schools is the content of technology, secondary justifications are still important. Technology teachers may not have to justify their subject inasmuch as they will have to politick for their subject. This chapter describes ten of the more significant secondary justifications for the inclusion of technology as a school subject (Figure 1). Most technology teachers choose three or four of these secondary justifications to emphasize at any given time with their students. Some of the justifications contradict others.

Figure 1. Justifications for technology studies



For example, critical technological literacy contradicts technological literacy and appropriate technology contradicts tech prep. Other justifications, such as gender equity, cut across all the others. Read this chapter with an eye toward recognizing the advantages and disadvantages of each justification. The first section addresses the significance of technology, which underwrites the primary justification, or the content of technology.

Significance of Technology

While technology is obviously relevant given its ubiquity and its role in restructuring international and social relations as well as our personal lives, it is still necessary to state the case for technology as a subject. The study and teaching of technology as a subject in its own right is important for the following, among other reasons. Why study technology?

- Technology is *central* to action, cognition, and emotion.
- The food we eat, the water we drink, and the air we breathe involve technological decisions.
- The scale and scope of technology are now extended toward two extremes of life: toward microscopic and macroscopic levels. Technologies now extend inward to minute cellular, molecular, and even atomic levels of our bodies and outward to the massive complexes of power plants, urban centers, and greenhouse gasses affecting the entire planet.
- Technology is increasingly imperfect and at the root of global public disasters such as nuclear meltdowns and local private disasters such as industrial cancer.
- Technology is increasingly integrated with all aspects of life, from amusement to domesticity to work. Technology is increasingly integrated into our bodies, leaving many to conclude that we are cyborgs. The artificial world and integrated circuit are ambient; increasingly, technology is habitat.
- Technology is increasingly final in that its effects are increasingly difficult to reverse. The elimination of species, ozone layer depletion and greenhouse gasses are significant for their finality.
- The monies directed toward technology amount to an increasingly large share of budgets in industry, the military, and government.
- Values, rights, liberties, and choices are affected by technology on immediate, personal levels.

- Technology is necessary for human existence. Personal livelihoods are dependent on technology for leisure, subsistence, and work.
- Technology is a fundamental area of culture and human endeavor, and is inextricably interwoven with history, culture, nature, and society; also, it is integrative in nature.
- Technology is problematic and paradoxical for individuals and society.
- The ubiquity and immediacy of technology redefine our perceptions of the world and ourselves. The new media technologies play ever more pervasive and invasive roles in our lives.

Increasingly, technology must be regulated and its direction subjected to limitations and determined democratically. There is tension between personal and social choice. Education is the only reliable route toward technological decision making and democratic choice.

Traditional, subject-centered education is permeated with technology, yet as a topic of study, technology is traditionally precluded to anything but passing glances or delivered at an impersonal, unreflective level. It typically is reduced to technoenthusiasm. The notion of the integration or infusion of technology into all subjects of the school is underwritten by the naive assumption that technology is merely a tool (technonaivete) and does not have to be studied as a subject. Some technologies may very well be tools, but in the aggregate with its collateral and deferred effects, Technology is a subject that demands and requires systematic study and deliberation. Technology studies happens to have developed a powerful theory and practice in C&I for this careful, sensitive study and deliberation to occur.

At this point, it is important to differentiate between the study of technology and the celebration of technology in schools. By celebration is meant advocacy or technoenthusiasm, or: (1) the promotion and endorsement of new technologies, (2) the uncritical dispensing of technical skills, and (3) optimism regarding the potential of technology to resolve social problems. The integration of the new media in school subjects amounts to a celebration of technology. The traditional subjects, such as industrial education, information technology education and career and technical education usually amount to technoenthusiasm. Technoenthusiasm in the schools fails the students, the future of the subject of technology in the schools and the democratic processes of society. The study of technology drops the pretension that basically any activity with, or course about, technology is justified. Technology is obviously important enough to be a subject of study in its own right, rather than merely integrated into all other subjects. The study and teaching of technology requires a more critical disposition and orientation toward technologies than is found in integration and the industrial approaches. The study of technology requires technoskepticism to temper the enthusiastic optimism that typically accompanies technology; a healthy criticism, rather then ambivalence. There are three ways that technonaivete mystifies technology and generates ambivalence:

1. The workings of contemporary technologies cannot be understood. Technology is beyond our understandings, inherently progressive, autonomous or beyond control. If it cannot be understood, it need not be studied, or understood. Technology is a tool to be taken for granted and used (instrumentalism).
2. Given #1, technology is like magic or alchemy come true. It is mysterious.

Given #1 and #2, technologies appear to have no history or location. They appear as products of their own production, as acts of autogenesis.

The mission of technology studies from this perspective means that technology teachers assume a challenge to demystify technology and its applications *as well as* re-sensitize students to the implications of their technological decisions and surroundings. This mission means providing experiences for young people to develop and question feelings, knowledge, and skills that empower them to participate in all facets of technological endeavor—from the practical to the political.

Technological Literacy

Standards for Technological Literacy define a technologically literate person as one who "understands, in increasingly sophisticated ways that evolve over time, what technology is, how it is created, and how it shapes society, and in turn is shaped by society. He or she will be able to hear a story about technology on television or read it in the newspaper and evaluate the information in the story intelligently, put that information in context, and form an opinion based on that information. A technologically literate person will be comfortable with and objective about technology, neither scared of it nor infatuated with it."

Technological literacy simply means "the ability to use, manage, and understand technology." Wright (1993, p. 7) offered a more detailed definition: "The knowledge and ability to use and communicate technological systems, ideas, and words." Neither of these definitions nor the description of a technologically literate person address capability, one of the most hotly contested issues of technological literacy. Dyrenfurth (1991) included capability, defining technological literacy as functional literacy:

Technological literacy is a concept used to characterize the extent to which an individual understands, and is capable of using, technology. Technological literacy *is a characteristic that can be manifested along a continuum ranging from non-discernable to exceptionally proficient. As such, it necessarily involves an array of competencies, each best thought of as a vector, that include: Basic functional skills and critical thinking, constructive work habits, a set of generalized procedures for working with technology, actual technological capability, key interpersonal and teamwork skills, and the ability to learn independently.* (p. 179)

To be technologically literate, does one have to be able to know about *and* do technology? If so, *what* does a technologically literate person know and do? To be visually literate does an individual have to do art? To be scientifically literate, does one have to do science? Technological literacy is currently the most popular justification for technology studies, and carries mass appeal with administrators, parents and the public. This concept is especially popular given the shear pervasiveness of technology in our lives. Surely, everyone should know and be able to do something about and with technology (Pearson & Young, 2002).

Technological literacy has its roots in what Charles Richards, in 1906, called "industrial intelligence," or mental power to see beyond the task which occupies the hands for the moment to the operations which have preceded and to those which will follow it—power to take in the whole process, knowledge of materials, ideas of cost, ideas of organization, business sense, and a conscience which recognizes obligations" (p. 334). The more recent notion of technological literacy was born out of the Engineering Concepts Curriculum Project (ECCP) during the early 1970s. The ECCP was funded by the U.S. National Academy of Engineering (NAE) and National Science Foundation (NSF) and culminated in a high school textbook titled *The Man-Made World*. For the ECCP, technological literacy was defined as an understanding of "the nature, the capabilities, the limitations, and the trends of technology" (Liao & Piel, 1970, p. 2). A technologically literate person understands "the nature, characteristics, limitations, as well as capabilities of modern technology and how this rapidly changing technology impacts upon their lives" (Liao, Piel, & Truxal, 1975, p. 99). *The Man-Made World*, despite its sexist title, was quite an amazing text, integrating the theme of technology, people, and the environment into a wide range of activities and lessons. However, it was not until the late 1970s and early 1980s that the concept of technological literacy was popularized, about the time that educators began to speak of computer literacy. Technological literacy was brought home to industrial education in 1978, in a conference paper given by Donald Lux, who was a key architect in the Industrial Arts Curriculum Project (Chapter VIII). This was also the time that many in Canada and the U.S. lamented the loss of competitive advantages in labor-intensive industries. Technological literacy enthusiasts argued that there was an increasing mismatch between the skills necessary to operate and build the new technologies used to innovate in manufacturing industries and the skills possessed by ill-prepared workers in the labor pool. Explained in terms of human capital theory, there was a strong relation between low skills and low productivity or profit. Spokesgroups for business and industry, such as the Conference Board of Canada (CBoC) (1996), jumped at the chance of defining a new workplace literacy. For those who were more inclined to look at impending cultural and ecological crises rather than economics, technological literacy had a different connotation. Science,Technology, and Society (STS) advocates, for example, noted that in the late 1970s and early 1980s, ecological disasters were increasing and becoming more spectacular with time (e.g., Three Mile Island, CFC's) and the microelectronics revolution was quickly making its way into all facets of leisure and work. With increasing share of everyday decisions demanded a knowledge of science and technology, like *The Man-Made World*, STS advocated a participatory literacy for all citizens. In effect, technological literacy became an amalgam infused with cultural, ecological, and economic hopes and concerns. One problem is whether to emphasize the economic components or the cultural and ecological components. Another is the progression of levels.

As Ron Todd (1991) proposed, we can think of technological literacy as a continuum of action, knowledge, and values (Table 1). Technological perception means that attention has been turned toward things technological. Technological expression means that technological questions, terms, and abilities can be used for cogent expression. Technological capability means that a range of technologies (e.g., communication, information, production, transportation) can be used in a range of applications. Technological ingenuity means that creative uses or inventions of technology can be demonstrated. Technological sensibility means that critical and discerning judgment can be brought to bear on technological decisions and policies. Todd's matrix is revised for Table 1.

Table 1. Taxonomy of technological literacy (Adapted from Todd, 1991)

Levels	Types of Knowledge	Competence
Technological Perception	Knowing what	Attention
1. Technological expression	Knowing what, that	Expression
2. Technological capability	Knowing what, that, and how	Application
3. Technological ingenuity	Knowing what, that, how, when, and why	Invention
4. Technological sensibility	Knowing what, that, how, when, why, and why not	Judgement

Technological Capability

Many technology educators argue that literacy is not enough. They argue that no matter how much we try, design and technical skills are not adequately included under the concept of literacy. Some of these educators settle for the concept of technological fluency. Fluency suggests a fairly effortless use of certain clusters of technology. Fluency refers to a transparency of technology, where users carry out tasks quite unaware of the technology they are using (Committee on Information Technology Literacy, 1999). Musicians playing their musical instrument are a prime example of fluency.

In England, the operative concept is technological capability, not literacy, or fluency. Technological capability is simply the potential for efficient, practical, quality work in design and technology. What should a student in grade 5, 8, 11, or 12 be capable of? How do we assess this capability? British educators of D&T have developed quite an elaborate system of assessments of capability and defined the concept so that it has substance. Capability is "a continuous engagement and negotiation between ideas and facts, guesswork and logic, judgments and concepts, determination and skills." According to Black and Harrison (1992, p. 54), "take action capability" in technology studies involves three dimensions:

- **Resources** of knowledge, skill, and experience which can be drawn upon consciously or subconsciously, when involved in active tasks.
- **Capability** to perform, to originate, to get things done, to make, and stand by decisions.
- **Awareness**, perception, and understanding needed for making balanced and effective value judgments.

Under this scheme, practical capability means that students can effectively draw on resources and make value judgments regarding these resources to get things done with a necessary level of skill.

As with technological literacy, the challenge is to define what a person should be capable of at particular points in their life. And like literacy, there are levels of ca-

Table 2. Levels of technological capability (Adapted from Dreyfus et al., 1986)

	Novice	Advanced beginner	Competent	Proficient	Expert
Aim	Accuracy and acceptance	Accuracy and independence	Fluency and independence	Fluency and demonstration	Characterization

Table 3. Bicycling capability profile

Grade	Technological capability
Second	Ride bicycle without training wheels, judge bike by visual appearance
Fourth	Ride bicycle, judge bike by visual appearance, oil chain, pump tires, customize bike with paint, judge bike by coolness
Sixth	Ride bicycle, judge bike by visual appearance, oil chain, pump tires, customize bike with paint, judge bike by coolness, ride no hands, re-engage chain, replace batteries in light, adjust handle bars, adjust brakes, judge bike by capability
Eighth	Ride bicycle, judge bike by visual appearance, oil chain, pump tires, customize bike with paint, judge bike by coolness, ride no hands, re-engage chain, replace batteries in light, adjust handle bars, adjust brakes, judge bike by capability, patch tire, balance in still position for 5 seconds
Tenth	Ride bicycle, judge bike by visual appearance, oil chain, pump tires, customize bike with paint, judge bike by coolness, ride no hands, re-engage chain, replace batteries in light, adjust handle bars, adjust brakes, judge bike by capability, patch tire, balance in still position for 5 seconds, replace brake pads, adjust gears, change pedals, replace brakes, change tire tube, adjust derailleur, judge bike by ergonomics
Twelfth	Ride bicycle, judge bike by visual appearance, oil chain, pump tires, customize bike with paint, judge bike by coolness, ride no hands, re-engage chain, replace batteries in light, adjust handle bars, adjust brakes, judge bike by capability, patch tire, balance in still position for 5 seconds, replace brake pads, adjust gears, change pedals, replace brakes, change tire tube, adjust derailleur, judge bike by ergonomics, change crank arm, replace link in broken chain, jump curb, design bike accessory, judge bike by economics and ecology

pability or competency that correspond with Dreyfus, Dreyfus, and Athanasiou's (1986) levels of skill acquisition explained in Chapter III (Table 2).

Of course, as with literacy, not everyone will be equally capable. Nor should the bar be set so high that no one is fully capable. Print literacy means that one can read and write, but not everyone can write a novel. What is a minimum level of technological capability for everyone? Should all students at the grade 12 level be capable of designing a Web page and maintaining it online? Should all grade 10 students be capable of scanning an image and incorporating it into a document? Should all students at the junior high level be capable of representing a simple birdhouse in an orthographic and isometric drawing? Should they be capable of designing and building a simple birdhouse? Should all students in grade 8 be capable of soldering electronic components into a simple circuit? How can teachers discriminate among levels of capability? Could we determine what students should be capable with regard to bicycling (Table 3)?

As indicated and as we will elaborate in Chapter VIII, the content of technology is distributed from capability to literacy. Disciplines of technology are distributed from mechanical to electronic to biochemical forms. Hence, technology educators

Table 4. Taxonomy for technological literacy and capability (Adapted from Tomei, 2005)

Literacy Understand technology and its components	• Understand technology in oral & written communication. • Use basic technologies.
Collaboration Share ideas and collaborate, form relationships through technology	• Share information about and through technology. • Use technology to facilitate collaboration.
Decision-Making Use technology in new and concrete situations	• Apply technology for problem-solving. • Design effective solutions to problems.
Discrimination Select appropriate technologies	• Appraise technologies to determine effectiveness. • Discriminate resources appropriate to problems.
Integration Create new technologies and resources	• Design, construct and implement new technologies and resources. • Use technologies to complement other technologies.
Technology in Society The study of technology and its value in society	• Analyze copyright laws and intellectual property rights. • Debate issues surrounding legal and ethical uses of technology. • Consider consequences of appropriate technologies.

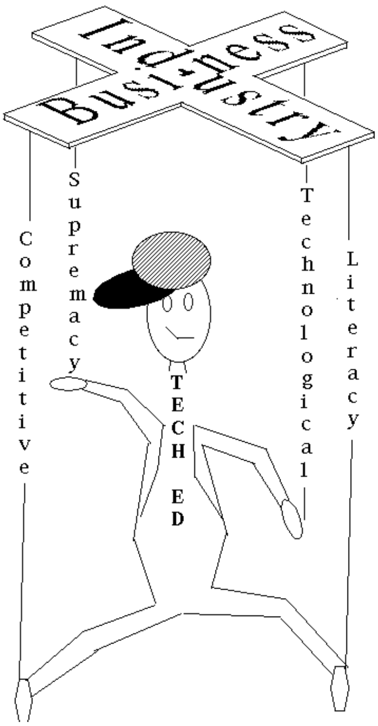
are challenged to reconcile capability and literacy as well as disciplines. There is an increasing trend in reconciling educational technology with technology education, which amounts to taking advantage of the new capabilities and literacies for work, play, and study in information-based societies. For Table 4, Tomei's (2002, 2003, 2005) "Taxonomy for the Technology Domain" was partially revised to demonstrate the potential of this reconciliation of capability and literacy.

Enthusiasts of technological capability have been unable to make their case in any coherent form. Schools have never been very receptive to sensorimotor skills or movement of the body. Physical education, art, music, and technology have had marginal roles in the curriculum of most North American schools. This partially accounts for the general failure of any coherent trajectory of technological capabilities in the schools. Enthusiasts of technological capability are also stymied by a middle and upper class logic suggesting that technological capabilities are unnecessary in an era where technical services can be easily purchased (but perhaps not so inexpensively purchased). Why should a student have to learn to replace an outlet or tune a car when their parent will pay someone to do it? Technological capability is currently getting a boost from new media in that everyone seems to want to know how to make hardware and peripherals respond to software. But again, if one is unable to configure a hardware system, help is just a phone call and $20.00 an hour away. Capability, reduced to instrumental competencies, is insufficient for critical literacy.

Critical Technological Literacy

What does it mean to be sensible and political in our technological practices? This is a question of ethics. It is a different question than "what does it mean to be literate about, and capable in, technological practice?" While values may be inherent in both, the first question politicizes one's participation in technological practice in

Figure 2. Technological literacy



such a way that a question of literacy does not. If technological literacy is merely the ability to use, manage, and understand technology, as it is defined by the ISTE and ITEA, technology appears to be neutral. An example of neutrality is the old saying that “guns don’t kill people; people kill people.” The assumption is that technology is neutral and it depends on how it is used that determines how we should judge it (e.g., consequentialism, Chapter III). For many technology educators, technological literacy is also neutral, and something nobody could be “against.” Hence, it has little potential to empower students with the dispositions, knowledge and skills to take action against forms and policies of technology that are unjust and damaging to ecologies and peace in the world. Critical theorists note that if citizens are passive, then literacy and technology serve the interests of business and industry (Figure 2). They note that technological literacy merely refers to the new competitive, economic maximizing, self-interested, yet somehow democratic, individual. Critical technological literacy provides a different orientation to literacy and capability (Petrina, 2000).

Beginning in the late 1960s, STS incorporated a form of critical technological literacy in C&I. STS aims to provide a general, critical literacy to empower students come citizens to participate in the politics of design and technology. This aim addresses the challenge of science and technology as dominant forces in societies where, for the most part, citizens are passive and participation in decision-making for technology remains elitist.

Critical technological literacy is sensibility. This means asking fundamental questions about what a particular technology offers or represents (*perception and description*), what it means and what is produced by its use (*analysis and interpretation*), and the technology’s worth (*judgment*). This means questioning technocratic assumptions, and capitalist notions of globalization and progress. Being sensible means acting politically, or intervening in the issues of inequity, injustice and exclusion that are invariably exposed through questioning. Of course, this active intervening entails the production of political artifacts or alternative technologies—the deconstruction, reproduction, and regulation of a political, built world.

If sensibility is a critical *intention* to engage ethically and perceptively, or politically with technological practice, then political action is the critical *agency* that animates and mobilizes alternative technological practices. While practice extends from the design to use of technologies, and from the “practical” to “political” endeavors with technology, it is important to see that these are indistinct. To be sensible about and politically active in a struggle against capitalist forms of consumption or waste is to be sensible and act against capitalist forms of production or deregulation. Where technological literacy was constructed through the gospels of consumption and production, critical technological literacy assumes responsibility for sensitizing students to the politics of these processes.

Table 5. Critical literacy profile

Critical Technological Literacy for Global Awareness

Critical awareness	Capacity to remain skeptical of fantastic promises and stories fabricated, for example, by business, the entertainment industry, governments, the media, military, or economics.
Ecological sensitivity	Ability to speak and act on behalf of sentient creatures and the earth.
Historical consciousness	Capacity to remember and witness historical inequities and injustices.
Labor empathy	Ability to act against labor injustices and for labor justice in the world.
Political reactivity	Quickness or acuteness of discernment and soundness of judgment needed in actions critical and political.
Relational responsiveness	Capacity to function empathically, openly and perceptively, in simple and complex relations.
Conspiratorial intuition	Capacity to recognize the differences between real and imagined conspiracies as they are formed and documented.
Technological ingenuity	Capability to use appropriate technologies to express creative counters to "jam" mass consumerism, resource exploitation and endless marketing.
Technological sensibility	Capacities of individuals and collectives to act critically toward decisions in technological practice, whether they be in leisure, work, or politics.
If technological sensibility is a critical intention to engage ethically and perceptively, or politically with technological practice, then political action is the critical agency which animates and mobilizes sensibility.	

Being critically literate of the built world means that we maintain a critical orientation or a different relationship to our technologies than has been the norm. Being critically literate of technology means that we have: (a) a critical orientation to technological literacy; (b) the sensibility or critical *intention* to politick against technological practices that sustain high rates of capital, consumption, inequities, and inegalitarian distributions of profit and waste; and (c) the political or critical capability or *agency* to mobilize and produce actions, products and alternative technologies that work against or "jam" the discourses and works of culturally and ecologically destructive technologies (Bettis & Gregson, 1993; Gregson, 1993; Petrina, 2000) (Table 5).

In critical technological literacy, a position of technological pluralism is adopted. This means that students ought to be exposed to a wide range of technologies throughout their education *and* a wide range of orientations to technology (alienation, instrumentalism, technoenthusiasm, technophilia, technophobia, luddism, technocriticism, etc). The only orientation towards technology that most students are exposed to is instrumentalism, or the *application* of technology to solve everyday problems or enhance problem-solving. Students are merely taught how technologies are used.

Rarely are students exposed to a wide range of philosophies that are critical and skeptical of technology (Bettis & Gregson, 1993). Criticism is integral to technology studies, just as art or music criticism is central to art and music. Just as we can be critical of art forms without being anti-art, we can critical of technology and not be anti-technology.

Culture jamming is a practice whereby critical resistance to commercial media is mobilized by turning mainstream, popular productions into a mockery. The goal of culture jamming, says the Media Foundation (2001), who publishes *Adbusters*, "is to galvanize resistance against those who would destroy the environment, pollute our minds and diminish our lives. We want to turn consumers back into citizens, take the 'consumer out of consumer culture, and shift the human experiment on Planet Earth back onto a sustainable path." This is accomplished through the production of advertisements that appropriate the work of corporations such as Calvin Klein or industries such as tobacco. Cultural images are selected for their consumer potency and then remade to jam or disturb that consumerism. The idea is that skills and technologies are used to counter trends in areas such as the treatment of animals, over-consumption, unemployment and waste. Appropriate technology and craft, described in the last two sections of this chapter, are two forms of technological practice that represent alternatives for working to overcome forms of power sustaining inequities in the built world. With all its potent power for resistance to mainstream culture, critical literacy often amounts to a few alternative projects and an emphasis on production at the expense of cognition and emotion.

Gender Equity

Some educators argue that technology studies can alone be justified on gender equity. Technology studies is seen as a potential intervention into a social problem of severe inequity in technological practice and participation. High-tech sector job growth doubled in North America during the 1990s while overall job growth was 15%. Yet, only 20% of the high-tech positions in Canada and the U.S. are filled by women. Females account for about 15% of the total product and industrial design graduates and about 90% of the graduates in textile design in Canada, England, and the U.S. In Canada, women account for between 0.51% (sheet metal fabricators) to 3.5% (machinists, painters/decorators) of all apprenticeships when chefs and hairdressers are removed from the calculations. The percentage of women completing baccalaureate degrees in engineering increased in the U.S. through the 1960s and 1970s but has remained between 15% and 20% of the total since the late 1980s. The number of female students taking the Computer Science College Board examinations did not increase between 1987 (17%) and 1997 (16%). A large number of girls and women

(a) remain limited to domestic, clerical, medical, and service *uses of* technology and (b) occupy subordinate *roles* in many scientific and technical fields. Women in the ITEA represent 68.9% of elementary, 14.5% of middle and junior high, 11.9% of secondary, and 8.5% of post-secondary profiles of technology teachers. In BC, one out of every thirty industrial technology and one out every eight information technology teachers are female. While women are more likely than men to work in an occupation requiring high amounts of computer use, girls are only one-twelfth (electronics) to one-fourth (information technology) as likely to complete a technology course as boys in high schools (Bryson, Petrina, Braundy, & de Castell, 2003; O'Riley, 2003; Petrina & Dalley, 2003).

In the secondary schools, today's percentage of young women enrolled continues to be extremely low but is better than it was during the 1970s and 1980s (6%-25%, depending on the technology course). Sanders (2001a, p. 43) found that girls account for 17.7% of enrollments in all high school technology courses in the U.S. In England and Wales, the enrolment of girls in secondary level technology courses was 21.5% in the early 1990s. In Canada, percentages differ across the country. Data collected in Ontario for the 1998-1999 school year suggest that the overall percentage of girls in senior technology courses is 19%; in BC technology education it is 7.9% and in information technology it is 24% (Bryson, Petrina, Braundy, & de Castell, 2003). In individual courses, such as construction technology, the enrollment of girls in Ontario is 15% and in BC this percentage is 8.4%. Actually, BC is a common example of the inequities in enrollments. The percentage of girls enrolled in grades 11 and 12 technology courses increased from 7.9% in 1987 to 10.3% in 1998. In construction 11 and 12 courses, the enrollment of girls was 11% and 6.5%, respectively, in 1998. The enrollment of girls in grade 11 electronics was 3.6% and in grade 12 the percentage of the total drops to 3.0%. Despite the relevance of electronics to high technology careers, this course has never been able to overcome the average 3% to 4% enrollment of girls. The girls' enrollment in power technology courses was 10% in grade 11 and 4% in grade 12. The communications technology courses have significantly higher enrollment rates than the other technology courses (24.3% in grade 11 and 14% in grade 12) (Table 7.6). The enrollment of girls in the senior, general technology courses increased by 3%, while total school enrollment increased by 26% in the same decade. The percentage of girls in grade 11 information technology courses dropped from 1986-1998 from 38.4% to 30%. Enrollments of girls declined in the construction, electronics, fabrication, and power technology courses.

As Mary Bryson and Suzanne de Castell (1996, 1998) have documented, the digital divide in the schools is found in the participation rates for girls in information technology, which have hovered around 20%-25% since its introduction into the schools in the late 1970s.

The problem of gender inequity in technology studies has a historical trajectory. Beginning in the 1900s and 1910s, working class girls were tracked into home

Table 6. BC enrollments by course and sex, 1988, 1998, 2002

Course	% Female 1987-1988	% Male 1987-1988	% Female 1997-1998	% Male 1997-1998	% Female 2001-2002	% Male 2001-2002
Info Technology 12	23%	77%	21%	79%	20%	80%
Construction 12	4.2%	95.8%	6%	94%	6.6%	93.4%
Drafting & CAD 12	11%	89%	14%	86%	14%	86%
Info Management 12	65%	35%	62%	38%	49%	51%
Foods & Nutrition 12	50%	50%	63%	37%	63%	37%

economics while the working class boys were tracked into manual training. This practice was naturalized over then next few decades, and by the 1950s, there were few who questioned the practices on sexist grounds. If the girls were not denied access to industrial (arts) education, they were counseled away from the workshops and laboratories. For the girls who demanded access and equity, there was no guarantee that problematic, gendered practices in the male-dominated spaces would be changed. To be sure, since the 1960s, some borders were crossed, but for the most part, we have been slow in overcoming the early historical precedents. By the mid 1970s, about 6.5% of the total enrollments in industrial education were girls, and about the same percentage of boys enrolled in home economics. Beginning in the mid-1970s, schools in North America were mandated to include about 100 hours of home economics and industrial education course in the "life skills" program of junior high school students. Many schools simply continued to track and stream boys into industrial (arts) education and girls into home economics. In junior high schools or the grades 8-9 levels of high schools of BC, students are typically required to take one or more of the "applied skills" courses (business education, home economics, and information technology) and many administrators make all of these a requirement (Braundy, O'Riley, Petrina, Dalley, & Paxton, 2000).

The issue of gender inequity is similar for technology teachers. Technology studies was introduced into the schools during the late 1800s in an age of separate spheres for women and men. But Karen Zuga (1989, 1996, 1998, 1999) stresses in her research that there were two points of origin for technology studies: elementary schools and high schools. A vast majority of the industrial arts teachers in the elementary schools were female; the high school teachers were male. In the late 1930s and through the 1940s, industrial arts was forced out of the elementary schools. By the 1950s and 1960s in North America, industrial arts was a high school subject. Elementary programs and female industrial arts teachers were rare by this time. The technologies selected as part of the high school curriculum were industrial, and represented industries in which the vast majority were males.

In the 1950s, there were laws and rules proscribing women's participation in technology, often justified as natural law. As well, the high school industrial educators defined what it meant to be a technology teacher, and this definition linked a particular form of masculinity with technology teaching. This masculinity was marked by a commitment to industrial forms of technology (versus domestic forms), emphasis on technical knowledge and skills, maintenance of privilege in access to technology, proprietary position on information, rugged individualism, and an identity defined in opposition to the feminine. Women entering the technology teaching profession since the 1950s have necessarily faced barriers: To be accepted within this predominantly male profession basically means acceptance of this form of masculinity. There is a similar story of racial inequity and segregation in North American schools. In the U.S., in the 1990s, about 1% of technology teachers were Native American, 0.2% Asian, 6.7% African American, and 2.2% were Hispanic. Data are nearly identical, and in places worse, across Canada. Racial equity advocates argue for interventions similar to those of gender equity advocates (O'Riley, 2003).

Gender equity advocates agitate against the subjection of girls and boys to forms of technological practice conditioned on particularly damaging forms of masculinity. Interventionist strategies in technology studies are also needed for boys—interventions of a different kind than for girls. Interventions that challenge our current cultural reinforcement of particular masculinities have been successfully implemented at the high school level (Bastone, 1995). Technology teachers have a special role in helping their male and female students in "Healing the Wounds of Masculinity"—by modeling more inclusive forms of masculinity (Connell, 1996, 2002; Koegel, 1994). This means dealing with gender as well as sexuality.

Gender equity advocates want to change the *status quo* by interventions into education. Equity advocates generally want to increase enrollments of girls in *some* technology courses to a 50-50 girl-boy ratio. They do not want to see females appropriated or used as numbers in defense of a technology studies while discounting females' perspectives and subjectivities. Inasmuch as girls continue to be under-represented in most technology-intensive courses, they have not benefited from investments in these courses. And so there exists a double inequity: (a) information and industrial technology courses continue to be over-funded in comparison to courses where female students predominate; and (b) only a small percentage of girls receive the benefits accrued through completion of these courses (Bryson, Petrina, Braundy, & de Castell, 2003). How can all of this be changed (i.e., made more equitable)? Most equity advocates agitate for interventions in two directions. From inside out, change the technology courses, the activities, facilities, and content—Change the culture of technology studies. From the outside in, change the policies (make more requirements), perceptions (better public relations) and personnel (targeted recruitment, affirmative action)—Change the optics of technology studies.

Character Values

Education to be effective for life, must be, like the conduct of life itself, both alert and patient, beginning where people are, and creating character rather than comfort, goodness rather than goods. It must be won rather than given, and based on faith in labor as a moral force. (Samuel C. Armstrong, 1919, quoted in Peabody, 1919)

I dream of the day when my children will be judged not by the color of their skin but by the content of their character. (Martin Luther King, 1963)

The development of character values has historically been an integral dimension of technology studies, as written into the charter of the Hampton Institute, an African American university established in the 1800s. Yet, the importance of character values has been overlooked. Advocates of character values argue that everything else is secondary in an age of global poverty, rash violence and wanton disrespect. On the Canadian television networks between 1993 and 2001, for example, incidents of physical violence increased by 378%. TV shows in 2001 averaged 40 acts of violence per hour. Incidents of psychological violence remained relatively stable from 1993 to 1999, but increased 325% from 1999 to 2001. In video games, the current trend is for players to act out criminal fantasies for earning points for attacking and killing innocent bystanders. Players in *Grand Theft Auto 3* (the best-selling game ever for PlayStation 2) earn points by carjacking, and stealing drugs from street people and peddlers. In *Carmageddon*, players are rewarded for mowing down pedestrians to sounds of cracking bones. MNet's 2001 study *Young Canadians in a Wired World* found that 32% of kids 9 to 17 are playing video games "every day or almost every day" and 60% cited action/combat as their favorite (Media Awareness Network, 2003). The Web site newgrounds.com, a favorite among teen boys, features Flash movies showing celebrities being degraded and killed. While the rate of young people charged with violent crimes in Canada and the U.S. is falling about 1% per year, the rate of youths charged with violent crimes is still about 75% higher than the early 1990s.

Technology studies, advocates note, can be a vehicle for developing and reinforcing character values, so desperately needed for at-risk students. Character values proponents argue that technology educators ought to make the disposition and temperament of students more explicit in everyday instruction. A framework developed in Washington, DC is an example of a character value-centered curriculum (Commission on Value-Centered Goals for the District of Columbia, 1988; Petrina & Volk).

Table 7. Character values

1. Self-esteem
   - Students should develop a strong sense of their own self-worth.
2. Self-discipline
   - Students should understand that responsible, creative work is the key to self-reliance.
3. Family, kinship, and belonging
   - Students should value and respect the family structure at home and at school.
4. Moral and intellectual maturity
   - Students should develop a respect for human dignity, care about the welfare of others, integrate individual and social responsibility, demonstrate personal integrity, carefully weigh moral choices and seek personal resolutions of conflicts.
   - Students should also be familiar with their history and understand their roles in contributing to the continuum of human history.
5. Responsibility to self and others
   - Students should respect the gift of healthy bodies and minds, appreciate the interdependence of all things, and behave compassionately towards others. They should learn by example and experience that unselfish service is a key component of self-gratification.

These character values are critical in the overall development of students. *Self-esteem* is a key component of self-realization and the development of a healthy outlook on life. Success-based technology activities build self-esteem. All too often, students are faced with challenges that are frustrating and not met. *Self-discipline* is a necessary ingredient for confronting and resolving daily problems. Technology studies has many features which encourage this self-discipline and perseverance. For example, the basic tenet of following directions for safety or the proper function of software or machines is an effective self-discipline developer in all technology courses. Self-discipline is manifested in craft or skill acquisition. Self-discipline leads to a sense of empowerment and *responsibility* for one's own destiny. This empowerment can be transferred to other areas of a student's life.

Through the design of emotionally sound instruction, technology teachers can develop a *sense of community* within the classroom. Technology studies labs and workshops often draw on cooperative learning to create a camaraderie which may be lacking in other classroom situations. Often and for many students in the schools, the technology labs and workshops are the only places where a *feeling of belonging* is present. Technology studies also develops a sense of *moral and intellectual maturity* and commitment to community and multiculturalism. Discussions involving the consequences of using particular technologies encourage students to weigh alternatives and resolve conflicts. Students can obtain a multicultural or anti-racist perspective on all cultures through the investigation of inventors, labor, and the relationships of all people to technology. These activities assist students in developing an *empathy for cultural, religious, and ethnic differences*.

The development of moral maturity and responsibility enable students to assume productive roles in society. Through projects and discussions that are relevant to the school and community, students are encouraged to examine and clarify their own value structures and behavior. Technology studies helps students realize that having a clear mind is a requirement of critical thinking, creativity, and technical skills. Technology studies also allows students to translate abstract ethical dilemmas and moral judgments into concrete classroom experiences that enrich other lives as well as their own. It is easy to be sympathetic with this justification. But this emphasis has the danger of producing the logic that as long as the students are busy and doing something then character values are being developed (Petrina & Volk, 1991).

Integration

Technology educators have proven themselves to be extremely effective at integrating across subject boundaries. The first reason for this is that technology is integrative by nature. To take technology seriously as a subject of study is to take this fact seriously. If we design with or study technological materials, we have to venture into chemistry, mathematics and physics, for example. When we transform the materials into objects and structures, we have to venture into economics, engineering, and psychology. When we study the effects of these objects, we have to venture into ecology, philosophy, and sociology. We use the technologies to communicate through the arts and humanities. The list could go on. The second reason that technology

Table 8. Integration

Integrate what? Apply what?
- Content, concepts, and subjects (disciplines).
- Skills and processes.
- Society and self.
- People.

How integrate?
- Subject correlation.
- Technology or occupation as vehicle to larger end (not end in themselves).
- Unit or project (environmental, social or technological problems).

Forms that integration has taken:
- Elementary school integration.
- Math, Science and Technology (MST).
- Science, Technology and Society (STS).
- Environment and technology.
- Engineering and materials science.
- Art, design, and technology.
- Home economics and technology.
- Research and experimentation.
- Applied academics (principles of technology).

Why integrate?
- Deal with complexity of the world.
- Overcome rigid subject boundaries.
- Respect seamless Web of knowledge.
- Promote greater efficiency.
- Holism or contextualism.
- Relevance.
- Amplification, augmentation.
- Disclosure, revelation.

To what (and whose) end?
- Technology as handmaiden to science.
- Science as handmaiden to technology (what is science and technology?).
- Technology as handmaiden to occupation.
- Humanizing the sciences and technologies.
- Rationalizing the humanities.
- Demystifying black boxes (how things work).

What are the tradeoffs?
- Autonomy for relevance & status.
- Independence for dependence.
- Integration for disciplinarity.

educators have proven themselves in integration is survival. Through the 1990s, it became apparent that technology educators would have to overcome isolation or face the impending consequences of irrelevance. Technology educators got their act together at about the same time that schools opened up to the possibilities of integration. While integration in the larger life of the schools is on the wane, the integration of technology into other subjects is well established (LaPorte & Sanders, 1995). But, integration refers to much more than the integration of subjects.

Elementary school educators will attest that isolation of subjects is a luxury, or less politely, a pathology of secondary schools. Manual training was introduced into the elementary schools in the late 1800s and diffused across the school much quicker than in the upper levels of schooling. In the elementary schools, teachers immediately integrated simple tools, materials, and processes into the curriculum. The technologies, or industries as they were called, lent themselves to easy expression by the students. But they also amplified the other subjects by making learning active and relevant. Design and technology in the elementary schools continue to percolate a potent brew of integration of subjects and people (Kirkwood & Foster, 1999).

At middle, junior, and secondary levels, the three most common clusters of integration have been math, science, and technology (MST), science, technology, and society (STS) and technology and environmental science. MST has been quite popular due to the affinities that math and science teachers have with technology teachers (Sanders & Laporte, 1995). Technology teachers, like math and science teachers, tend to be rational and prefer to focus their interests toward objective problems that are challenging and ultimately solved. Applications of mathematical and scientific principles are readily disclosed through engineering and technology. Art and technology are natural pairs, generally in a context of design. STS typically draws on the humanities to address controversies and consequences deriving from science and technology. Technology and environmental science are a provocative combination, but the integration continues to be a challenge due to the general neglect of ecology in the science curriculum (Elshof, 2003; McLaughlin, 1994, 1996, 2001). The integration of home economics and technology education also offer a rich encounter. Here, technology figures into domestic labor, family health and wellness, nutritional science and consumer awareness.

The integration of "educational technology" into all subjects is the most contentious form of integration. The logic of this integration treats technology as merely a tool rather than a subject to be studied. Integration can be a powerful justification, but in some forms it can undermine the study of technology as a subject.

Employability Skills

Ultimately, there are certain skills that societies value at certain times and certain skills that groups within these societies value. There are ethical and political judgments made on certain skills at certain times. What do employers expect from the students that they hire? What are the societal expectations of high school graduates? When should these attitudes, literacies and skills be developed? What subjects should address these? Whose expectations should we value? Small businesses may have different expectations than large businesses. Technology studies can be justified at some levels by appealing to the opportunities students have for developing and practicing employability skills.

The Conference Board of Canada (2000) provides an example of employability skills, or basically combinations of cognitive, social and motor skills. Employers tend to suggest that soft skills ought to be developed in the schools as generic traits that all students should possess. The hard skills, they argue, can be developed on-site in individual businesses and industries. In fact, many countries are witnessing the decimation of trades systems due to this "just-in-time" logic of business and industry. The combinations of skills defined in the interest of business are typically not the combinations defined by other interest groups in education. The U.S. Secretary of Labor's Commission on Achieving Necessary Skills (SCANS, 1991) are similar to the skills listed in the Canadian skill set. SCANS identified a generic skill set for succeeding in a changing economic climate (Table 9).

SCANS argued that students should develop five competencies that built on a foundation of *basic skill*s (e.g., literacy, numeracy), *thinking skills* (e.g., problem-solving, reasoning), and *personal qualities* (e.g., integrity, responsibility). Technology educators who emphasize employability skills point out that these skills can also be applied and used beyond the workplace in a range of daily activities. Specialized technological skills rarely transfer to occupations and can become obsolete in an era of rapidly changing technology, SCANS and advocates of the employability skills justification point out.

Advocates of the employability skills justification argue that economies of the developed world have transitioned from an industrial to post-industrial status (Table 10). This translated into a transition from industrial education to post-industrial education, and computer science to information technology, or technology studies. Where industrial education dealt with heavy, specialized skills related to primary resource and material-specific industries, technology studies deals with light, flexible processes, new materials and digital information. Post-industrial societies require different employees and citizens than do the industrial societies.

Analyses of both manufacturing and service industries identify a shift away from practices that support a high volume business based on single products or services. To remain competitive, an increasing number of businesses are responding

Table 9. SCANS' five competencies (Adapted from SCANS, 1991)

SCANS five competencies (1991)
Resources: Identifies, organizes, plans, and allocates resources
1. Time: Selects goal-relevant activities, ranks them, allocates time, and prepares and follows schedules.
2. Money: Uses or prepares budgets, makes forecasts, keeps records, and makes adjustments to meet objectives.
3. Material and facilities: Acquires, stores, allocates, and uses materials or space efficiently.
4. Human resources: Assesses skills and distributes work accordingly, evaluates performance, and provides feedback.
Interpersonal: Works with others
1. Participates as member of a team: Contributes to group effort.
2. Teaches others new skills.
3. Services clients/customers: Works to satisfy customers expectations.
4. Exercises leadership: Communicates ideas to justify position, persuades and convinces others, responsibly challenges existing procedures and policies.
5. Negotiates: Works toward agreements involving exchange of resources, resolves divergent interests.
6. Works with diversity: Works well with men and women from diverse backgrounds.
Information: Acquires and evaluates information
1. Acquires and evaluates information.
2. Organizes and maintains information.
3. Interprets and communicates information.
4. Uses computers to process information.
Systems: Understands complex interrelationships
1. Understands systems: Knows how social, organizational, and technological systems work and operates effectively with them.
2. Monitors and corrects performance: Distinguishes trends, predicts impacts on system operations, diagnoses deviations in systems performance and corrects malfunctions.
3. Improves or designs systems: Suggests modifications to existing systems and develops new or alternative systems to improve performance.
Technology: Works with a variety of technologies
1. **Selects technology:** Chooses procedures, tools, or equipment including computers and related technologies.
2. **Applies technology to task:** Understands intent and proper procedures for setup and operation of equipment.
3. **Maintains and troubleshoots equipment:** Prevents, identifies, or solves problems with equipment, including computers and other technologies.

Table 10. Post-industrial expectations

Expectations for students in post-industrial societies

Autonomous learning ability	Ability to learn how to learn
Basic employment competencies	Ability to function as a worker (dependable, cooperative, efficient, flexible)
Communication fluency	Ability to express feelings and thoughts
Computational competency	Ability to apply basic math skills to solve problems

Table 10. continued

Coping ability (change and conflict adaptability)	Ability to deal with change and continuity
Creative problem solving ability	Ability to respond and think in novel ways and situations
Interpersonal diplomacy competency	Ability to deal with conflict and to relate with others through emotion and words
Leadership & organizational effectiveness ability	Ability to take charge and act with an organization when necessary
Intrapersonal management competency	Ability to resolve inner conflicts and setbacks
Planning ability (individual & organizational)	Ability to organize, plan and maintain plans for simple events and tasks
Reasoning competency	Ability to apply logic in solving and trouble-shooting social and technical problems
Safety & health competency	Ability to maintain safe and healthy environments and to act in safe, healthy ways
Listening, speaking, and graphic competency	Ability to communicate through graphic, oral and written means
Scientific & technological capability & literacy	Ability to assess and use scientific and technological information and tools

to consumer demands by increasing the variety of products and services offered. This trend is particularity evident in manufacturing industries that were typically tooled-up for high volume production and low-skilled labor. Productivity, in both office and factory, is being driven by the demand to utilize workers with a wide range of *basic skills* to get the most out of investments in new technology. Trends toward automation in offices and factories, and accompanying managerial changes are facilitating the development of workplaces that are technologically complex, dependent on cooperation, and responsive to imperatives of customization. Workers who have a strong foundation of basic skills or, in essence, are skilled in interpersonal communication, have the capability to learn and adapt quickly, and the facility for troubleshooting and solving problems are especially valuable. Rather than beginning with the skills learned in the workshops and labs and projecting outward for a hopeful transfer, employability skills proponents begin with the requirements of employees and project inward to redesign and curriculum to meet the new skills.

This often means little more than business and industry dictating the objectives and goals of education. Certainly, technology teachers will want to balance their emphases on the skills defined in the interest of business and industry with the skills defined in the interests of rights and liberties groups. The expectations of business typically differ from the expectations of labor. The expectations of environmental or media activists usually contradict the values of business representatives. There are cultural differences in expectations. So how can a teacher, or the profession of technology studies, respond to this range of interest groups? Can we afford to be neutral? What about our own values? One certain economic issue seems to be the preparation of students for the service industry. Despite the new economy, the vast majority of jobs will be "MacJobs" in the service sector over the next decade.

Tech Prep and Technical Trades

During the 1990s, technology educators made a case for establishing secondary school technology as pre-engineering, pre-high tech trades, technical preparation, or "tech prep," for technical careers (Colelli, 1993). In the tech prep model, technology courses in the secondary schools are aligned with the curriculum of colleges and institutes of technology to ease transitions. In the best case scenarios, tech prep courses are accepted for post-secondary credits and skills developed are transferable to the technical careers of interest. In a tech prep scenario, technical careers and trades legitimate and validate technology studies. The technical careers and trades confer status for technology teachers in this case. Tech prep and career education define the essential imperative of technology studies in terms of economics. Technology studies must "pay off" as a cultural and capital investment for students and society, according to tech prep proponents. The brunt of accountability for effectiveness here falls in the hands of teachers, teacher educators, administrators and elected officials.

Proponents of tech-prep, like employability skills advocates, are betting on economic changes and new demands on the labor force in North America. Forecasters suggest that the emerging economy is restructuring the way that goods are produced and services delivered. Consumption and production mixes within amenity groups such as food, housing, health, personal business and communication are being transformed by competition within a global market, and changes in consumer and labor demands. Requirements for prosperity under new conditions are marked by, among other trends, global competitiveness, a reliance on a skilled workforce, investments in new technology, development of complex workplaces, workers with a broad range of skills, and managerial changes. A global market has emerged and is characterized by shifts of production from goods to services, application of new technologies to most industries, gains in productivity, deflation in world prices, and increased competition for skilled labor. Increased international dependence means that sustained economic growth depends on competitive industries. Competition requires industries to either cut wages, lay-off workers and maintain the current level of production or increase productivity. To increase productivity, industries are turning toward foreign, low-skilled, low-wage labor markets, technological change, changes in workplace management, and workers with a command of basic skills. Economic forecasters suggest that there will not be a continued need for a large, low-skilled labor pool. The demand to remain competitive has shifted requirements toward skilled labor at home, and contracts to low-skilled, low-wage labor abroad (Petrina, Craven, & Powell, 1993).

Although automation affects different industries in different ways, nearly every office and factory will automate to reach an optimum level of production at an acceptable cost. In Japan, despite its depression, automotive industries have automated to the extent that vehicles roll off the assembly line with 10-30% fewer labor hours than those in North America. Automation necessarily means that labor intensive processes are replaced by technically sophisticated machines; but, it can also enhance other processes. One resultant trend is the deskilling and elimination of low-skill jobs and, at the same time, an upskilling of peripheral jobs, especially in manufacturing industries. This is the shift that tech prep is betting on. Proponents also bet on shortages in the technical trades in North America.

Many economic forecasters predict a shortage in technical careers and trades of North America through 2010 (Renshaw, 2002), but the numbers will never be adequate to justify the existence of technology studies in the schools. For example, only 2.5% of the students in BC secondary schools have any desire to make a transition into a tech prep or apprenticeship program after graduation, and only 1.3% actually enroll in an apprenticeship program while in school (Petrina & Dalley, 2003). The largest percentage of these students transition into hair stylist or chef training, neither of which are in the technology curriculum. The fastest growing trades are in the BC film industry where two-dozen new categories were created in the between 1998 and 2003. Another 6% of BC students transition into college career technical programs. The majority of these students enter IT and business related programs and more and more of these students are graduating from a vocational high school. These schools are technology career magnet high schools, and have the potential to completely usurp technology education's already tenuous economic identification with tech prep and trades. About 96% of skilled crafts and tradespersons are male (when cooks and hair stylists are removed). The high-tech sector (i.e., high-tech manufacturing, IT and related services, engineering services, and medical laboratory services) is the fastest growing economic sector in North America. In 1998 in BC, for example, the high-tech sector's contribution to GDP was 6.2%, 20 times the 0.3% expansion rate of the BC economy. High-tech sector job growth doubled during the 1990s while overall job growth was 15%. But the high-tech sector, like the technical trades, is male-dominated, with an 80% male employment rate. Tech prep, through an association with either the trades or high-tech sectors may be suspect as a male enterprise. This changes however, when health occupations and medical technologies are included as part of technology studies (Petrina & Dalley, 2003).

The service sector, along with high-tech sector growth, will account for 90% of net new jobs in North America through the decade of 2000-2010. Service jobs in the accommodation and food industries and wholesale and retail sales have been, and will account, for a majority of this growth. More than a few technology educators nevertheless have been willing to gamble on the tech prep justification assuming that high tech programs will translate to high skilled jobs in a changing economy (Hagenbaugh, 2004; Nightingale & Fix, 2004). Economic forecasts are contradictory at best, but the issue is not solely economic. It is questionable whether tech prep proponents are committed to "at-risk" populations or have adequately addressed gender and race in high-tech professions. Economic crises might be best met if the revitalization of technology programs centers on diverse student needs, at-risk populations, and problems of economic and gender inequities.

Appropriate Technology and Ecodesign

Appropriate technology (AT) has had a checkered past within technology studies. During the 1970s, when AT was on the ascent in North American governments, it was quite common to find technology educators involved in do-it-yourself projects of affordable housing, alternative energy and vehicles and third world economics. In the 1980s and early 1990s, this interest in AT faded only to be revived again during the late 1990s. AT is most commonly associated with E. F. Schumacher, who was agitating for humane, economic practices as alternatives to state and corporate capitalism during the 1960s and 1970s. But he was not merely providing models for what he called an "economics as if people mattered." He was interested in an economics as if animals, plants, and the ecology of Earth mattered. He emphasized the importance—to people and to nature—of technological practices that were cheap enough for common use, were simple enough in technique for common use, and relied on local knowledge, labor, and materials for the production of things for local maintenance and use. Indebted to the work of Gandhi, Schumacher referred to this as "intermediate technology" which was qualitatively different from the poverty-reinforcing tools in much of the southern hemisphere and the large-scale, power-hungry tools of the northern hemisphere. Eventually intermediate technology was popularized as "Alternative Technology" and "Appropriate Technology" (AT) in India, North America and various parts of the world (Petrina & O'Riley,

Table 11. Schumacher's model for AT

AT is:	• Controlled by those it employs.
• Simple	• Contributes to providing secure livelihood.
• Small Scale	• Financially self-supporting.
• Low-Cost	• Serves the local community and is accepted by it.
• Non-Violent	• Uses local sources, materials and services.
	• Uses sustainable fuel and raw materials.
	• Causes no environmental damage.

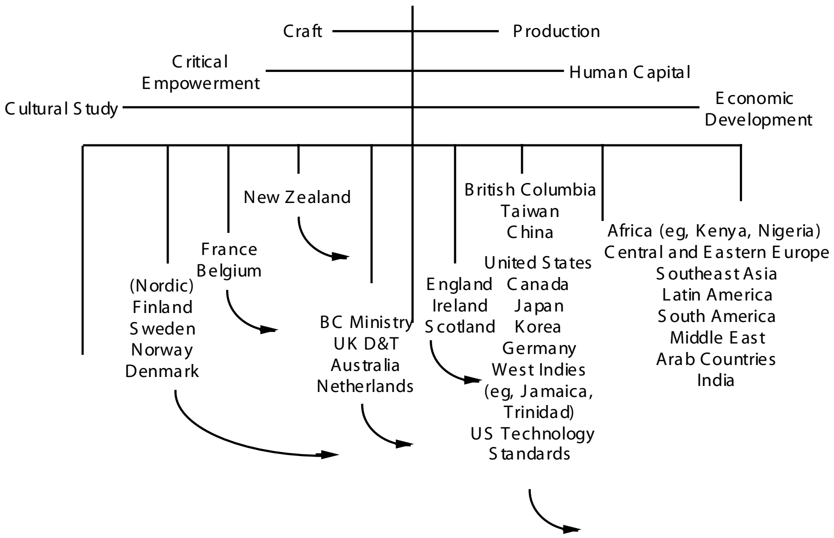
2001). AT has defining characteristics that differentiates it from other ways of approaching technology.

Schumacher's model for AT was based on Buddhist values of simplicity and non-violence. Instead of belaboring choices between "modern growth" and "traditional stagnation," or between "materialist heedlessness" and "traditional immobility," Schumacher used the Buddhist value of the Middle Way to position AT as a middle or intermediate path between distinctly different styles of technological practice. In Buddhist, economics there is a concern for simplicity and non-violence in both material means and ends. If a desired end is an attractive jacket to wear on a cold winter day, then the desired task is to create a garment with the smallest destruction of material and natural resources and with a design that requires the smallest input of toil and import of capital. Designing a complex labor-saving machine to perform complicated tailoring with large swaths of imported cloth is a folly and contradiction of the value of simplicity. At the same time, designing for a maximization of production and complicated tailoring which invariably result in an exploitation of resources is a barbarity and contradiction of the value of non-violence. In joining the values of simplicity and non-violence, Buddhist economics encourage a reverence for and celebration of all sentient beings and inorganic matter (Petrina & O'Riley, 2001).

Agencies such as the World Bank and United Nations also tuned into AT and sustainability, but it wasn't until the late 1980s that sustainability was placed alongside development on a global agenda. "Sustainable development" was popularized through circulation of the World Commission on Environment and Development's (WCED) (1987) report titled *Our Common Future*. Sustainable development was "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (p. 43). The WCED or Brundtland Commission began by arguing for the need to live equitably within a delicate ecosphere.

> The Earth is one but the world is not. We all depend on one biosphere for sustaining our lives. Yet each community, each country, strives for survival and prosperity with little regard for its impacts on others. Some consume the Earth's resources at a rate that would leave little for future generations. Others, many more in number, consume far too little and live with the prospects of hunger, squalor, disease, and early death. (p. 27)

Figure 3. International trends in technology studies



There are a number of technology educators who argue that AT be the driving force behind technology studies. AT, they argue, combines critical literacy and capability to provide technology studies with an ecological and social purpose. The projects in AT education promote self-sustainability and global awareness. AT proponents point out that international trends in technology studies point dangerously toward economic development and toward competitive supremacy (Figure 3). The economic power derived from technology studies, they counter, ought to take the form of AT (Petrina & O'Riley, 2001; Wicklein, 2001).

AT enthusiasts often compromise AT philosophy, emphasizing the activity of making alternative artifacts over knowledge necessary to counter capitalism. The main message of AT is lost on the production of artifacts. AT is closely aligned with craft.

Craft, Design, and Engineering

Handicraft, or craft, is an antidote to high tech, shoddy quality, mindless consumerism and the ugliness of capitalism, or so its proponents argue. Craft plays on concerns that something valuable is being lost in our creation of virtual environments and sedentary lifestyles that consumerism and cyberculture encourage. Craft was always responsive to labor, or vice versa, and today symbolizes the value and dignity of labor. Craft is part and parcel with the history of technology studies, but was given a boost in England through the craft, design and technology initiatives of the 1960s and 1970s. Craft for the English schools was defined as follows (Penfold, 1988):

Handicraft is specifically concerned with all aspects of the artifact and its creative production. The complete productive sequence includes need identification, data collection, design proposals, workshop realization, and ultimately evaluation of product against the need. The sequence can be entered into at any of the stages mentioned and each of them brings to bear upon the problem a variety of scientific, mathematical, aesthetic, social and communication disciplines. Artifacts of the past and their production direct attention to technological, social and aesthetic developments in their history; the nature and behavior of materials within the production process involves their practical examination in numerically precise terms; technological developments, design opportunities, and ecological balance reaffirm the social responsibility of the designers. The subject is therefore seen as the practical context of a liberal education. (p. 24)

Advocates of craft stress this last point, noting that all students ought to have an opportunity, as part of their liberal education, to design and make functional objects under the direction of a teacher. They make no pretension that craft will have academic or occupational pay-offs. Rather, craft dispositions, knowledge, and skills are part of what it means to be a well-rounded person. Craft takes its subject to be the artifact—the crafted work—which offers a focus for a broad range of understandings. Currently in England and Wales, the craft curriculum is divided into craft activity and craft inheritance. Craft activity refers to active involvement in the designing and making of one-off individual artifacts, cultivating the imagination and practical skills, visual sensitivity and a working knowledge of tools and materials. Craft inheritance refers to activities targeted at cultivating knowledge and understanding of the historical, technological and cultural contexts in which artifacts have been and are made (Crafts Council, 1995).

The arts and crafts movement of the 1800s rejected the modern factory for its degradation of labor and its manufactured product, and addressed the decorative arts as a fusion of art and technology. By the mid 1910s, the arts and crafts philosophy of handicraft was sympathetic to the use of machines. Schools such as the Bauhaus in Germany demonstrated that the use of machines did not have to come at the expense of craft skills and good design. Within the Bauhaus during the 1920s, art and technology, or craft, were unified in design *for* the modern factory and mass produced objects (Figure 4). Design and engineering—art, craft and science—were fused. So craft stands against mass production and for the reform of factory-produced goods through design. Craft means good design and fair economic conditions for labor.

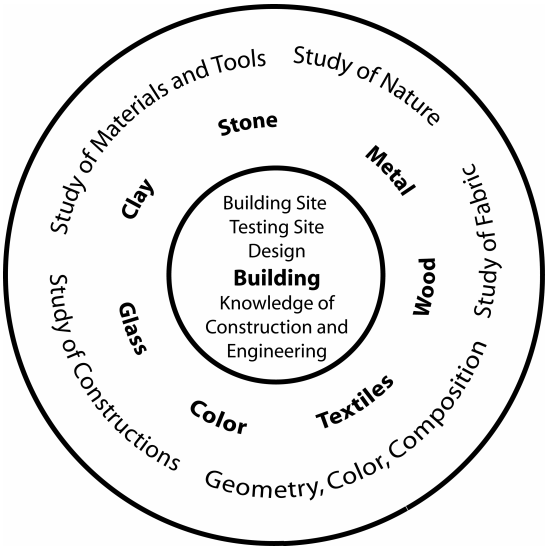
Labor as a subject worthy of study in its own right nearly disappeared from industrial education and technology studies through the last half of the 20th century. Few teachers were willing to teach the ways and means of union activism. Indeed, some of the most significant changes of the century had come through union's education of workers, and not through public schooling. Craft provides a way of addressing labor and union issues without resorting to abstractions. Today, craft embodies basically the same message of the arts and crafts movement that began in the mid 1800s. The craft manifesto, recently written, could have been written a century ago (Metcalf, 2002, p. 16):

- Craft stands against anonymity and for the personalized object.
- Stands against ugliness and, on occasion, for beauty.
- Craft stands against big-money capitalism and for small-scale entrepreneurship.
- Craft stands against corporate labor, where most workers are replaceable parts in a bureaucracy, and for individual self-determination.
- Craft stands for the rich potential of the human body at work and against disembodiment in all its forms.

Craft, design, and technology were fused in the curriculum of English schools during the 1960s and 1970s. In Chapter V, design was addressed within a context of creativity and ingenuity. The fusion of design and technology continues to be highlighted in counties such as Australia, New Zealand, UK, and the U.S., but technology teachers nevertheless tend to be less sympathetic to craft and design philosophy and labor than the practices of craft production. In this way, craft is responds to a justification that technology studies ought to be a place for individual expression and personal relevance. Similar to art education, an emphasis on the design and production of personal items in technology studies compromises craft philosophy. While craft accommodates Aboriginal philosophies of labor, resource and the land, Aboriginal artifacts are often constructed in technology studies with little regard for either craft or sustainability. Woodworking tends to be the epitome of craft without philosophy or sustainability. There is no question that many students develop an avocational appreciation and strong feelings for woodworking. We tend to over-romanticize craft in the schools. In reality, craft often amounts to mere capitulation to student desires, busy work and the production of *any* artifact in the name of craft, design, or technology. Most often, craft is merely doing things and making stuff.

Similar to art therapy, craft is often employed for its therapeutic values. Proponents of craft therapy subscribe to the philosophy that the act of working raw materials into decorative or utilitarian objects has curative and restorative values. Throughout

Figure 4. Bauhaus curriculum, ca. 1918



the twentieth century, craft was employed for special needs students who often had remedial and physiotherapeutic needs. This craft therapy philosophy permeated industrial (arts) education, and is regularly used to justify the heavy emphasis on doing and making in technology studies. Those who appeal to design and technology in the curriculum are challenged to demonstrate to stakeholders that this means more than craft therapy.

Since the 1970s, design in technology studies diverged on two trajectories: toward architectural, graphic and industrial (product) design on one trajectory and toward engineering design on the other. Architectural, graphic and industrial design are sources of aesthetic and ergonomic knowledge while engineering design is a source of material, mechanical, and structural knowledge. The intersection combines the art of craft and design with the precision of the engineering sciences. In fact, this intersection of art and engineering was what made the Bauhaus immensely productive and unique in the 1920s (Figure 4). Since that time, design education has emphasized aesthetics and originality (custom design) over mechanics and fabrication (mass production).

Engineering education was originally for disseminating "useful knowledge" of craft and trades to the working classes. It was practical. But by the late 1870s, engineering was yielding to corporate demands and scientific knowledge (Noble, 1977, pp. 20-49). Hence, the field of engineering made its crafts and trade roots subordinate to the engineering sciences. Shop culture and practice became secondary to school culture and theory. Today, the difference between "engineering technology" and "engineering" post-secondary programs (see Introduction) reflects this subordination. Engineering generally remained in post-secondary institutions until the 1960s when the Engineering Concepts Curriculum Project (ECCP) team wrote *The Man-Made World* course and textbook. Instead of organizing *The Man-Made World* by disciplines, engineering was reduced to three major *concepts*: Energy, Materials and Systems, primarily information systems. The intention was not to prepare students for engineering, but rather to provide all students with an understanding of modern technology. The emphasis was on MST, which makes advocates quite comfortable with an engineering justification for technology studies. These advocates tend to prefer an engineering design orientation for MST (Lewis, 2004, 2005; Rogers, 2005). Others choose to organize technology studies according to chemical, electrical, civil, genetic, and mechanical engineering—according to the disciplines (see Definitions).

Projection and Reflective Practice

In the previous half of the book, we dealt more or less with the issue of instruction. This chapter begins the second half of the book which focuses on curriculum. Ten justifications for technology studies were described in detail in this chapter. We acknowledged that teachers tend to choose three or four of these at any given time to emphasize with their students. The justifications amount to orientations of approaches to technology studies education. Some teachers approach technology studies with a technological literacy and capability focus, others approach technology from a critical perspective. Some orient their programs toward tech prep while others focus on appropriate technology. While these ten orientations are not exhaustive of all justifications, they are the most popular. It was stressed that the primary justification for technology studies was technology content, underpinned by the significance of technology in the world today. The ten justifications provided are secondary and ought to be used to reinforce the content of technology. In other words, after a century of inconsistency and independence from school to school, the survival of technology studies in the schools depends on consistency and the content justification. The sun is setting on the "do-your-own-thing" era of technology studies. The profession has matured. In the next chapter the content and standards of technology studies will be addressed. Rank the top three justifications for yourself to put this chapter in perspective. Your top three justifications will be moderated by your values and background. Try to be sympathetic to the remaining seven. Do not dismiss any outright, as they will all serve you from time to time.

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Chapter VIII

Technology Content, Process, and Standards

Introduction

If status of a school subject is at issue, then content, benchmarks, and standards cannot be underestimated. Of course, the question is what content and what (or whose) standards? Technology has suffered as a school subject in many ways because of the lack of consistent content and a defensible set of standards. What technology should a student in grade 2 know about and be able to use? What about grade 6, grade 8, grade 10, or grade 12, at graduation? What are the benchmarks for each grade level? We do not yet know. Should we have consistent technology content and standards for all students from K-12? Should all teachers abide by the content and standards? Should we have exams to monitor the students and teachers? Or should teachers have the freedom to teach what they want? If a student moves from one school to another, he or she will face a different curriculum with different goals. But the teachers will have the freedom and power to make professional judgments about what to teach. Who should make these judgments?

As indicated in the previous chapter, there is one, and only one, persuasive justification for the inclusion of technology studies in the schools. That justification is the content of technology. As recent as ten years ago, we were unable to speak of "the content" of technology in North American schools. The situation has changed and persuasive cases have been made to move technology studies from the margins of the schools to the center. Technology is now an extremely relevant subject in its own right, with a well-established curriculum and fund of instructional methods. In Chapter VII, we began with a comprehensive rationale for teaching technology in the schools. This chapter deals generally with content and standards, and specifically with the most recent projects to specify content and standards for technology studies.

Consistency in content and standards from school to school has always been a contentious issue. In no subject has this been more contentious than technology. To date, technology teachers in North America have enjoyed near total liberty in offering any curriculum they pleased. Currently, Canadian students who move from one province to another, or from school to school, are penalized for the lack of consistency from province to province. In the U.S., this has also been the case, with differences between states, districts, and schools. Technology studies differs from school to school in BC and students or teachers who relocate find little, if any, consistency and continuity. Even the names are inconsistent. There is no examination system to generate consistency and hold teachers accountable to standard sets of content. Nevertheless, this is changing through content standards for technology. Consistency, articulation, and accountability are the operative words in technology studies at this point.

Technology Content

There are fundamentally three sources of content: individuals, culture, and nature. Content derived from an individual will be developmental, physical, or psychological. Content derived from nature will tend to be biological or ecological and based on basic needs and survival. Content derived from culture will be institutional, sociological, or spiritual. The emphases of content derived from each source will range from practical to academic. Over the past century, technology teachers have derived content from all three sources. Currently, technology educators are focusing their efforts on content derived from culture, or more specifically, from a structure or discipline of technology. The source of content has always been contentious in technology studies, partially due to our activity-based practices and partially due to the changing state of technology. How can we establish stable content when technology is inherently dynamic? Should we focus on technological processes, which tend to be transferable? Should we focus on technological occupations and tasks, which tend to be accessible and current? Should we focus on technological concepts, which tend to be durable? There is not an airtight argument to be made for any of these social sources of content. Each has its benefits and problems. However, given the politics of the schools in this new century, where survival depends on establishing a subject as an academic discipline with coherent K-12+ content, technology educators must choose wisely. And the wisest choice at this time is disciplinary content, not the content of processes or occupations. If necessary, disciplinary content can be ordered to serve the content of processes or content of occupations. Either way, disciplinary content must take priority.

We derive content through a number of methods. The content of a discipline is derived from a *conceptual analysis* of facts, concepts, generalizations, and theories established over time. The content of occupations is derived from a *task analysis* of work and workers at specific points in time. The content of processes is derived from a *systems analysis* of processes and methods at specific points in time extended over time. To do a conceptual analysis, one has to make logical inferences from established principles and existing problems. To do a task analysis, one has to make procedural observations of tasks. To do a systems analysis, one has to make systematic observations of problems or processes. The point is that we can derive social content from disciplines, processes or problems and tasks. In most cases, a curriculum consists of combinations of disciplinary content, processes, and tasks. Of course, disciplines, problems, processes, and tasks change over time. Values and priorities also change. The materials, process and task-based content of industrial (arts) education and audio-visual education is not as relevant today as it was in the 1950s and 1960s. The trend is toward disciplinary content in the technology curriculum.

Technology Content and Standards

Currently, in many countries there are efforts to reform the K-12 curriculum for all subjects by forming a defensible set of standards to make content consistent from school to school. For example, the International Technology Education Association's (ITEA) (2000) *Standards for Technological Literacy: Content for the Study of Technology* project is making technology content consistent and forming a defensible set of academic standards for the study of technology. The International Society for Technology in Education (ISTE) (2000) established standards for the study of information technology and published *National Educational Technology Standards*

Table 1. Definitions of standards

Academic standards are basically statements that clearly define what a student should know and be able to do. There are:
Content standards: What students should know and be able to do.
Performance standards: How students demonstrate that they meet a standard.
Proficiency standards: How well the students must perform.

for Students. In England, the Department for Education Standards established technology content and standards and published *Design and Technology in the National Curriculum* in 1995. Education standards for all subjects can be found in Kendall and Marzano's (1997) *Content Knowledge: A Compendium of Standards and Benchmarks for K-12 Education*. There are basically three kinds of academic standards: Content, performance, and proficiency standards.

The ITEA's and ISTE's standards projects deal primarily with content and performance standards. Both projects were initiated in the mid 1990s amidst national and international incentives to make the study of technology consistent. The relationship between the two projects is set to subset. The ISTE's standards can be seen as a subset of the ITEA's standards. ISTE has dealt specifically with information technologies where the ITEA dealt generally with the entire scope of technology, including information technology. The ITEA's standards extend over five broad themes: Nature of Technology, Technology and Society, Design, Abilities for a Technological World, and the Designed World. These standards are providing an effective blueprint for the creation of a scope and sequence of content for technology subject at the K-12 levels. The question we asked in Chapter VII, "what should all students know about and be able to do in technology?" is being resolved. We now

Table 2. ITEA's (2000) standards for technological literacy

The nature of technology	
1.	Students will develop an understanding of the characteristics and scope of technology.
2.	Students will develop an understanding of the core concepts of technology.
3.	Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
Technology and society	
4.	Students will develop an understanding of the cultural, social, economic, and political effects of technology.
5.	Students will develop an understanding of the effects of technology on the environment.
6.	Students will develop an understanding of the role of society in the development and use of technology.
7.	Students will develop an understanding of the influence of technology on history.
Design	
8.	Students will develop an understanding of the attributes of design.
9.	Students will develop an understanding of engineering design.
10.	Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Table 2. continued

Abilities for a technological world
11. Students will develop abilities to apply the design process.
12. Students will develop abilities to use and maintain technological products and systems.
13. Students will develop abilities to assess the impact of products and systems.
The designed world
14. Students will develop an understanding of and be able to select and use medical technologies.
15. Students will develop an understanding of and be able to select and use agricultural and related biotechnologies.
16. Students will develop an understanding of and be able to select and use energy and power technologies.
17. Students will develop an understanding of and be able to select and use information and communication technologies.
18. Students will develop an understanding of and be able to select and use transportation technologies.
19. Students will develop an understanding of and be able to select and use manufacturing technologies.
20. Students will develop an understanding of and be able to select and use construction technologies.

have a defensible set of technology standards; we are approaching a comprehensive scope and sequence of content for study.

The breadth of these standards is quite comprehensive and inclusive, encompassing nearly all facets of technology. This is one aspect of technological pluralism at work. These standards name the scope of what is to be studied and place parameters around the disciplinary content of technology. ISTE's standards focus specifically on information technology and primarily on the use of technology. Quite often in the education, we hear naive assertions that "technology is merely a tool." A tool is certainly a technology, but technology is not merely a tool to be used for tasks. As indicated in the previous chapter, technology is a subject to be studied. We need to be very careful of overemphasizing the "use" of technologies as this may come

Table 3. ISTE's (2000) technology foundation standards

Basic operations and concepts
• Students demonstrate a sound understanding of the nature and operation of technology systems.
• Students are proficient in the use of technology.

Table 3. continued

Social, ethical, and human issues

- Students understand the ethical, cultural, and societal issues related to technology.
- Students practice responsible use of technology systems, information, and software.
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity.

Technology productivity tools

- Students use technology tools to enhance learning, increase productivity, and promote creativity.
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works.

Technology communications tools

- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences.
- Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences.

Technology research tools

- Students use technology to locate, evaluate, and collect information from a variety of sources.
- Students use technology tools to process data and report results.
- Students evaluate and select new information resources and technological innovations based on the appropriateness for specific tasks.

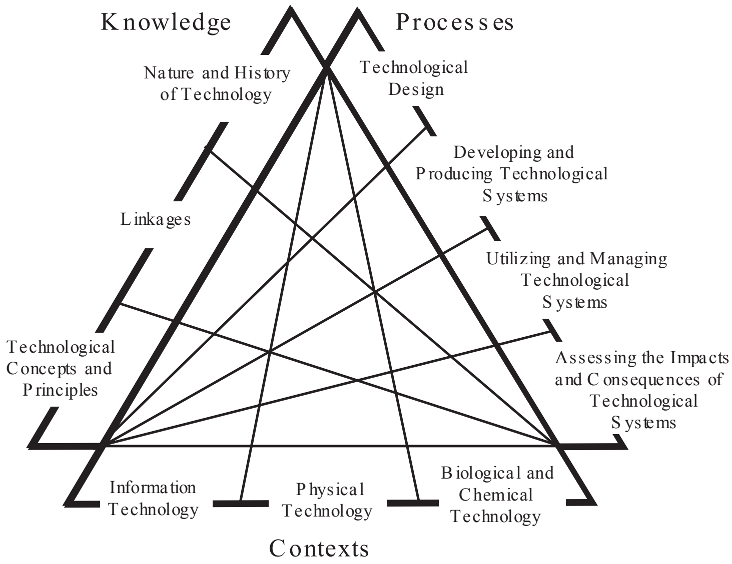
Technology problem-solving and decision-making tools

- Students use technology resources for solving problems and making informed decisions.
- Students employ technology in the development of strategies for solving problems in the real world.

at the expense of actually studying the technologies we use. We cannot justify an entire curriculum on the use of technology. Granted, the Standards for Technological Literacy covers a fairly comprehensive range of technologies that include the information technologies.

Rhe ITEA's and ISTE's standards are arranged according to similar content organizers (Table 4). Although this is by coincidence rather than by design, the organizers

Figure 1. ITEA's Organizers for technology standards (Adapted from ITEA, 1996, p. 17



for each set of standards complement and validate each other. But again, the ITEA's organizers are more comprehensive than ISTE's.

The ITEA's standards are derived from a discipline of technology arranged by contexts, knowledge, and processes (Figure 1). The base of the discipline is grounded on the forms that technology takes or the general sub-disciplines with which we

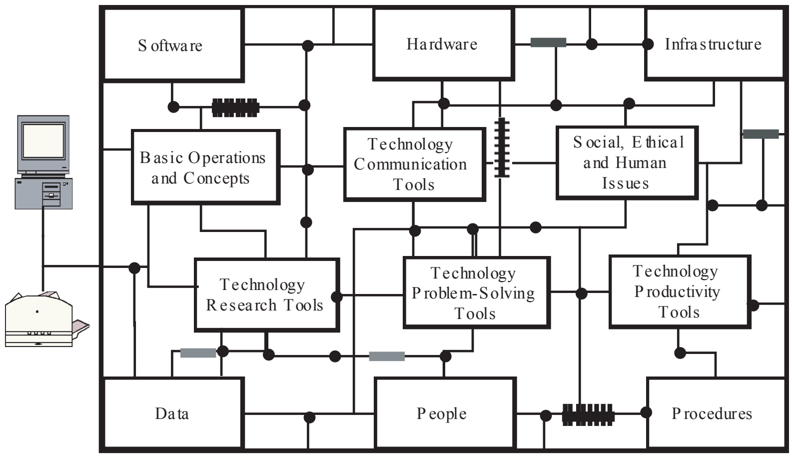
Table 4. ITEA's and ISTE's content organizers

ITEA organizers	ISTE organizers:
• Technological concepts and principles.	• Basic operations and concepts.
• Technological design.	• Technology communications tools.
• Developing and producing technological systems	• Technology productivity tools.
• Utilizing and managing technological systems.	• Technology problem-solving and decision making tools.
• Linkages.	
• Nature and history of technology.	• Technology research tools.
• Assessing the impacts and consequences of technological systems.	• Social, ethical, and human issues.

associate technology: Information technology, Physical technology, and Biological and Chemical technology. This is a departure from traditional sub-disciplinary organizers such as communications, production, and transportation. In another section, this tendency toward more general organizers is explained. These organizers are broad enough to accommodate a wide range of technological knowledge (concepts, history, linkages, and principles) and processes (assessment, design, development, management, production, and utilization). At another level, biological, physical, information and physical technologies are sub-divided into the technologies that most technology educators recognize: agricultural and related biotechnologies, energy and power technologies, information and communication technologies, medical technologies, construction technologies, manufacturing technologies and transportation technologies. Agricultural technologies, biotechnologies and medical technologies bring school subjects such as agricultural education and health occupations education into the fold of technology studies. At the lower levels of schooling, all of these technologies are included in the single subject of technology or integrated across the curriculum. At the upper levels, the entire spectrum is handled in one course, in some cases, and across several subjects, in most cases.

ISTE's standards and organizers are derived from a practical field that merges educational technology with information and communication technology (Figure 2). This is both an advantage and a disadvantage. The advantage is that ISTE's standards can be easily integrated across the curriculum with little or no need for a separate subject of information technology. Of course this can be a disadvantage if we take the position that technology is a subject to be studied in its own right, and not merely integrated (Chapter VII). The disadvantage of combining educational

Figure 2. ISTE's organizers for technology foundation standards



with information technology is that there is not a coherent discipline from which to derive content. The result is that the curriculum of information technology cannot be derived from ISTE's standards or organizers. In Chapter I, the discipline of information technology was described as an outgrowth of computer engineering and science. As we proceed through this chapter, keep in mind the fact that information and communication technology (ICT) is a sub-discipline of the discipline of technology. The two sets of standards should not be interpreted as being in competition with each other. ISTE's standards are a subset of the ITEA's standards for technology studies.

Technology Content, Standards, and Benchmarks

The technology content standards are backed up by benchmarks and performance standards. Basically, content standards derive from well-articulated disciplines and fields. Benchmarks and performance standards derive from content standards, and proficiency standards from these performance standards. Ultimately, classroom activities, assessment, lessons, and projects are derived from these different types of standards. This is the rational procedure to follow. The reverse direction, where a structure of content originates from activities and projects, cannot lead to consistent practices in a subject. The challenge is to subscribe to the technology discipline and standards while developing locally based activities and projects to meet the standards. The challenge is to adopt a consistent structure of content and standards and then proceed toward local innovation. Standards have to be translatable for practice. Teachers must be able to express the standards in their practices at all levels.

Consistency, articulation, and accountability are the operative terms at this point in time. Consistency is a necessary step towards accountability. If technology teachers are consistent in the content they teach from school to school then technology studies can be accountable to its constituents. Articulation is dependent on consistency and accountability. It is somewhat easier to establish consistency than an articulation of content and knowledge over the K-12 system. What should a grade 6 student know about technology that a grade 5 student does not know? The task of articulation is extremely challenging but essential to subjects. I encourage all technology teachers to survey the ITEA's (2000) Standards for Technological Literacy: Content for the Study of Technology and ISTE's (2000) National Educational Technology Standards for Students. Kendall and Marzano's (1997) Content Knowledge: A Compendium of Standards and Benchmarks for K-12 Education is also invaluable in helping you pay close attention to the articulation of content from level to level.

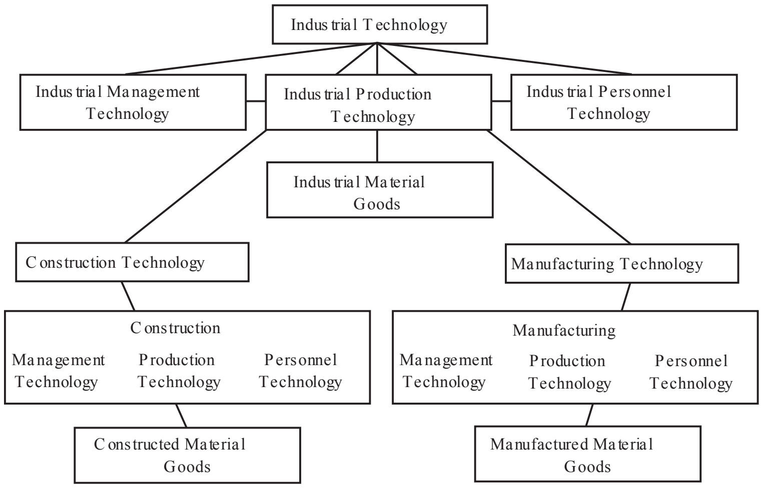
The Disciplines of Technology

The new content and standards of technology are derived from various disciplines of technology. There is a range of disciplines of technology just as there are different disciplines of science. One way of illustrating this is in engineering. The discipline of engineering consists of chemical, civil, electrical, genetic, and mechanical engineering. There are various sub-disciplines such as acoustics, aeronautics, avionics, ballistics, bionics, electronics, dynamics, hydraulics, mechanics, pneumatics, optics, robotics, statics, and synthetics. Each sub-discipline is a discipline in its own right. We can say that all the engineering disciplines collectively form the discipline of engineering. Design has its own disciplines (architectural, interior, etc.), as does communication or production. Ought the disciplines of technology include only technical fields, or does technology extend to social fields as well? Some scholars limit disciplines of technology to technical fields and isolate technology from other fields of study. Others expand technology to include political, psychological, and social fields. This is why it is more accurate to speak of disciplines rather than a discipline. Disciplines depend on what is included and excluded.

Charles Richards epitomized proto-theorists of the technology disciplines and initiated a progressive outlook on content that continues today. In 1904, in his now famous essay, "A New Name," he introduced the term "industrial art" to designate an integration of art and industry and to replace an outmoded practice of "manual training." The discipline of industrial arts education (IA) was to be derived from "nothing short of the elements of the industries fundamental to modern civilization," or as he said in Art in Industry, from the graphic, mechanical and textile arts. After expanding on Richards' and Dewey's work, F. Gordon Bonser, Lois Mossman, and James Russell at Columbia University defined the discipline of IA for the elementary schools during the 1910s and early 1920s (Foster, 1995a, 1995b). The IA discipline was organized by food, clothing, and shelter with the intent being "industrial insight, intelligence, and appreciation" (i.e., technological literacy). The trend towards disciplinary content was a direct reaction to prevailing emphases in the high schools on drafting, metals and woods, and the process of deriving content by task analysis. The trend, identified in the 1930s, was toward deriving content from the major industries (communication, power, production, and transportation) (Herschbach, 1984; Lewis, 1995).

When William E. Warner introduced A Curriculum to Reflect Technology in 1947, he named technology as the proper subject for industrial arts, rather than industry. Warner and his students envisioned a study of technology, rather than industries such as drafting, electricity, graphics, mechanics, metals, and woods. Industrial arts was, in theory, focused on conditions, materials, tools, processes, and products of these industries. In practice, it was merely a conglomeration of narrow procedures and projects derived from task analysis. For Warner, the most forward-looking way to organize industrial arts was through a study of five broad technological orga-

Figure 3. Industrial technology discipline (IACP)



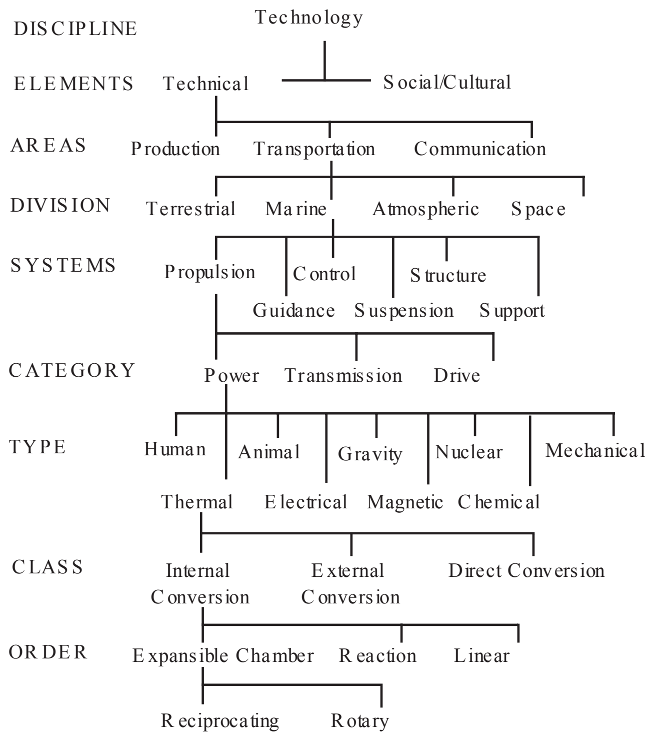
nizers, derived from a socioeconomic analysis: communication, construction and manufacturing, power, and transportation. The naming of these sub-disciplines of technology was a major breakthrough for technology studies.

A second major breakthrough came a decade later with Delmar Olson's graduate thesis (as Warner's student) titled Technology and Industrial Arts (1957) and his subsequent book, Industrial Arts and Technology (1963). More than anyone prior to this time and for the following decade, Olson provided an entire K-12+ curriculum and justification for the study of technology. With his book, Olson popularized and elaborated on Warner's work and the discipline of technology. The sub-disciplines of technology were: construction, electricity and electronics (energy), industrial organization and management, industrial production, power and transportation, research and development, and services. Communication was embedded in services and distributed across the sub-disciplines. This discipline of technology was oriented toward industrial technology.

Following the steps of Warner and Olson, in 1966 Edward Towers, Donald Lux, and Willis Ray published A Rationale and Structure for Industrial Arts Subject Matter, or what they called the Industrial Arts Curriculum Project (IACP). The IACP limited the technology discipline to industrial technology, based on a socioeconomic analysis of classification systems. Industrial technology was divided into construction and manufacturing, which in turn sub-divided into management, personnel and production. These sub-divisions sub-divided and so on (Figure 3).

The IACP provided a logical basis for the selection of content in an industrial technology curriculum. Activities and projects were developed for the attainment of content and understanding of the discipline. The IACP was routinely used in about

Figure 4. Technology discipline (DeVore, 1964)



2,700-3,000 junior high schools in the U.S. by the late 1970s (Lux, 1979). Industrial technology, nevertheless, proved to be too limited. For example, communication and transportation were subordinate to construction and manufacturing.

DeVore remedied this problem, but created another, in 1964 with his Technology: An Intellectual Discipline, which was somewhat of a revisiting of Warner's 1947 curriculum. For DeVore, the discipline of technology divided into production, transportation, and communication. The production area sub-divided into divisions of manufacturing and construction; manufacturing into the categories of fabrication and processing; fabrication into five types and so on. This provided teachers with a basis for valid content selection (Figure 4).

Activities and projects were formed with the attainment of content and an understanding of the discipline of technology, or more specifically, the sub-disciplines of communications, production, and transportation. Creating confusion, he suggested that power and energy were distributed across these three industries. Nonetheless, the primary goal was to develop an understanding of content rather than the development of skills in one or another process or occupational area. The message was this: Use a conceptual analysis of a technology discipline rather than task analysis of industrial work to derive content.

The 1960s were an extremely active time for the disciplines of technology (Cochran, 1970; Householder, 1979). Notable initiatives included The Alberta Plan, specifically Man, Science, Technology, which identified the sub-disciplines of technology to be computer, electronic, graphic communication, mechanical, power transmission technologies. In 1966, this was among the first technology disciplines to include computer technologies as a sub-discipline (Ziel, 1971). Today, the technology discipline for content and standards in the schools is expansive and sweeping, inclusive of most except military technologies.

Task Analysis

Task analysis quickly rooted in industrial arts and audio-visual education during the 1910s and 1920s. At that time, task analysis was called "trade and job analysis." Trade and job analysis was a technique for taking an inventory of skills and procedures necessary to complete tasks. The inventory was taken for either instruction or for documenting the efficiency of workers. This process was based on the techniques developed in the early 1880s by Frederick W. Taylor, who argued that there was "one best way" to performing any individual task. For instance, there was one best way of shoveling coal, one best way of soldering seams, one best way to type, and one best way of ironing clothes. Taylor called his techniques "scientific management." Scientific management required a documentation of the movements and procedures of workers, typically with a stopwatch and often with a movie camera. He called these time and motion studies. The scientific manager reviewed the documentation and recommended to managers how the procedures of workers could be reduced to a one best procedure, supposedly to increase efficiency. A required number of shovels or key strokes per minute were now expected of workers, who would be re-trained to work according to the one best procedures prescribed by the scientific manager. Managers, such as Henry Ford, loved the process. Workers and labor unions despised scientific management. The monitoring software used in workplaces today is a remnant of scientific management, or Taylorism.

Taylorism proved to be an inspiration to educators who figured that the one best way of doing job tasks must be the model for teaching industrial procedures and skills. In 1919, Charles Allen published The Instructor, the Man, and the Job, effectively a manual for translating the practices of scientific management into instructional planning, or trade and job analysis. Selvidge's How to Teach a Trade reinforced this in 1923. Through the 1930s, educators such as Frykland and Selvidge managed to orient the entire curriculum of industrial arts curriculum toward trade and job analysis. Eventually in the 1960s, trade and job analysis was reduced to task analysis, still with us today. Generally, task analyses involved an analysis of the following aspects:

- **Duties and tasks:** Performance of specific tasks and duties. Information is collected includes frequency, duration, effort, skill, complexity, equipment, and standards.
- **Environment:** Related to the physical requirements to perform a job. The work environment may include unpleasant conditions such as offensive odors and temperature extremes. There may also be definite risks such as noxious fumes, radioactive substances, or hostile and aggressive people.
- **Technologies:** Some duties and tasks are performed using specific technologies. This may include protective clothing or safety equipment.
- **Relationships:** Relationships with internal or external people during the task.
- **Requirements:** Abilities, dispositions, knowledge, and skills required to perform the job. Basically the minimum requirements for adequate performance.

Trade and job analysis is designed to identify the work requirements of specific jobs by providing a detailed overview of the tasks that must be performed by workers in a given job. Task analysis, a step in the process of job analysis, is conducted to identify the details of specified tasks, including the required dispositions, knowledge, and skills required for successful task performance. There are basically four kinds of task analysis (Lankard-Brown, 1998):

1. Worker-oriented task analyses focus on general human behaviors required of workers in given jobs.
2. Job-oriented task analyses focus on the techniques in performing job tasks.
3. Cognitive task analyses focus on the cognitive components associated with task performance.
4. Emotional task analysis focuses on the emotional elements associated with task performance.

Rather than isolating one type of task analysis from the other, high-tech workplaces are demanding that single-focused task analyses give way to combinations that reflect the greater breadth and depth of skills required for high-tech jobs.

Worker-oriented task analysis typically involves observations of job tasks performed by workers, interviews with workers, review of tasks by supervisors and surveys to determine the value of tasks and the knowledge and skill requirements. A job-oriented task analysis is a systematic process for collecting information about the highly specific and distinct tasks required for particular jobs. Job-related task analyses rely on workers and supervisors who can explicitly state the step-by-step sequences of tasks and procedures. Cognitive task analysis attempts to determine the thought processes workers follow to perform the tasks and identify the knowledge necessary to perform the tasks at various levels (e.g., novice or expert). It is a process used to gather information on behavior in problem-solving situations that highlights the constructive nature of everyday knowledge and social constraints on problem-solving. Cognitive task analysis relies on the techniques of observation and interview.

Basically, task analysis involves the process of breaking complex behaviors (chain of simple behaviors that follow one another or occur simultaneously) down into their component parts. A comprehensive task analysis involves the use of task inventories, interviews, and observations. Simplified task analyses are based on observation and reflective practice.

Task analysis has witnessed a revival with the new information technologies. The complexities of software applications and related peripheral interfaces have required that instructors pay close attention to the performance of tasks. In response to the heavy reliance on task analysis, critics have pointed out that the information technology curriculum has become top heavy with procedural knowledge and utilitarianism. Given that applications and peripherals change so rapidly, technology teachers are challenged to teach content that is current. The rapid changes of content (derived from task analysis) in the new technologies have led some educators to promote the teaching of transferable processes over content.

In technology studies, task analysis plays an important role as both a technique to derive content for C&I and a teaching method. Task analysis is essential to teachers for organizing procedural knowledge, whether if is cognitive or sensorimotor oriented.

It is also a teaching method to engage your students in procedural knowledge and career education. Teachers who prioritize the role of task analyses tend to prioritize

Table 5. Task analysis (simplified)

1.	Identify a task to be analyzed.
2.	If possible, isolate the task from other tasks.
3.	Identify the goal of the task.
4.	Identify any special technologies necessary for task completion.
5.	Identify any special safety considerations.
6.	Focus on the essential elements (essences) of the task.
7.	List detailed sensorimotor steps of the sequence of the task from start to finish.
8.	List detailed cognitive steps of the sequence of the task from start to finish.
9.	List detailed emotional steps of the sequence of the task from start to finish.
10.	Condense detailed steps into a clear, concise, manageable procedure.
11.	Perform the task by following the new procedure and revise as necessary.

Table 6. Task analysis example how to scan

1.	Launch scanner application (double click on icon at bottom of screen).
2.	The software should locate the scanner (if it is powered up and connected).
3.	In new pop-up window, click on "Preview" (assuming you have already positioned the image to be scanned on the scanner bed upper left corner) (Tip: it is best to leave settings at their defaults).
4.	After preview, crop to-be-scanned image by pulling dotted-line window around desired image.
5.	Click on "Scan."
6.	In new pop-up window, name image file (e.g., image1.jpg or image1.gif).
7.	Save file in "Student Temp Files" folder or on hard drive. (You can copy to your own floppy or zip disk after you are finished).
8.	Click on save (the file is now written and exported to the destination folder as a JPEG or GIF file).
9.	Start over at step #3 if scanning a second image.

competencies and capability over content and instrumentalism over critical empowerment. In other words, doing tasks does not automatically lead to knowing about technology and making sense of the effects that we feel. Performing technical tasks may be a necessary condition for literacy about technology but it is not a sufficient condition in itself for this literacy.

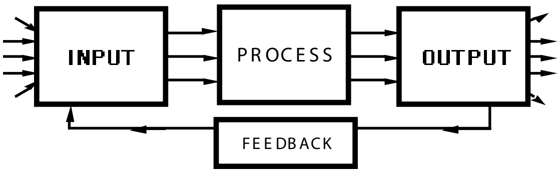
To edit image, it is recommended that you use Graphic Converter (for basic editing) or Corel Photo Paint or Adobe Photoshop (for advanced editing)

Processes as Content

The conceptual analysis of the discipline of technology and the task analysis of the activities of technology represent two alternative techniques for deriving the content of technology studies. Rather than one or the other, some technology educators suggested that there could be a middle path, where the processes of technology would be the content of technology studies (Hutchinson & Hutchinson, 1991). They integrated conceptual analysis with task analysis to derive content.

Technology processes have been part and parcel of the trend toward disciplinary content, most notably in Olson's Industrial Arts and Technology and the American Industry project of the 1960s. In American Industry, common processes were identified at the core of all industries. These included energy and materials procurement and processing, communicating, producing and transporting, financing and property acquisition, research, planning and maintaining industrial relations, marketing and management. Units such as Operating an Enterprise focused on process such as ideation, invention, prototyping, and marketing, organizing a business, planning for

Figure 5. Cybernetic system



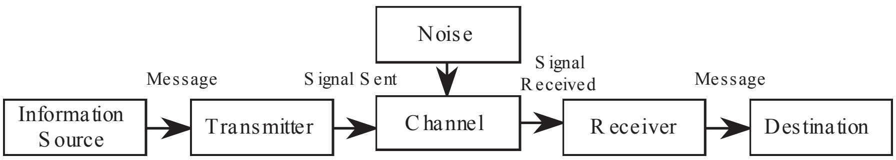
production, surveying market needs, inspecting products, selling and accounting. American Industry recognized the ways that public interests and private property conflicted, and the give and take among competition, resources, and the government of economies.

Drawing from these processes and the trends toward disciplinary content, technology educators in the U.S. set a course to establish processes as content for the curriculum of technology studies. The Jackson Mills Curriculum Theory of 1981 was an initial step to integrate technological processes and the discipline of technology. Similar to DeVore's discipline, Jackson Mills reduced technology to a series of "universal" systems that included communication, production, and transportation systems of technology. This shifted the emphasis from the processes of American Industry to processes of systems. Students were to develop a sense of how systems were designed and operated, laying the groundwork for a curriculum based entirely on systems logic and processes. In cybernetic grammar, activities and projects were developed to give students an understanding of technological systems of inputs, processes, outputs, and feedback loops. The processes of design and technology were reduced to a simple cybernetic system (Figure 5).

Communication systems demanded a different treatment to capture human-to-human, as well as machine-to-human and machine-to-machine communications. Here, students were to grasp not only the cybernetic system model, but also communication systems as captured in Shannon and Weaver's classic model (Figure 6). The emphasis was placed on the systems and processes of technology rather than the products.

This general shift toward a process-based curriculum came in 1989 with the Conceptual Framework for Technology Education. The Conceptual Framework adopted

Figure 6. Model of communication (Adapted from, Shannon and Weaver, 1949)



the systems approach as a given and designated problem-solving processes as the basis for content. The shift was from system processes to human and intellectual processes; from questions concerning what technologists produce to those concerning what they do and think as they design and produce. Problem-solving was simplified as a six step process: (1) define the problem, (2) reform the problem, (3) isolate solution, (4) implement plan, (5) restructure plan, and (6) synthesize solution. This process, or what was called the "technological method" in the Conceptual Framework, was supposedly adaptable to any form of technological content (Savage & Sterry, 1990). This shift echoed the emphases on design in the British technology curriculum. In fact, many educators argued that the proper referent for technology studies was design. Coinciding with the rise of information technology, processes as content allowed teachers to shift their preoccupations with specific software packages to the processes underlying the applications.

The turn towards systems and processes inspired teachers to focus on what was transferable despite the technology or software. In CAD, for instance, rather than concentrating on the commands of AutoCAD and associated skills, teachers began

Table 7. Intellectual processes of technologists (Wicklein & Rojewski, 1999)

1.	**Analyzing:** The process of identifying, isolating, taking apart, breakdown down, or performing similar actions for the purpose of setting forth or clarifying the basic components of a phenomenon, problem, opportunity, object, system, or point of view.
2.	**Communicating:** The process of conveying information (or ideas) from one source (sender) to another (receiver) through a media using various modes. (The modes may be oral, written, picture, symbols, or any combination of these.)
3.	**Computing:** The process of selecting and applying mathematical symbols, operations, and processes to describe, estimate, calculate, quantify, relate, and/or evaluate in the real or abstract numerical sense.
4.	**Contextualizing:** Understanding the social, cultural, organizational, etc. context for the task.
5.	Creating: The process of combining the basic components or ideas of phenomena, objects, events, systems, or points of view in a unique manner which will better satisfy a need, either for the individual or for the outside world.
6.	**Customer analysis:** The process of evaluating inputs of the receiver or technology.
7.	Defining problem(s): The process of stating or defining a problem which will enhance investigation leading to an optimal solution. It is transforming one state of affairs to another desired state.
8.	**Designing:** The process of conceiving, creating, investing, contriving, sketching, or planning by which some practical ends may be effected, or proposing a goal to meet the societal needs, desires, problems, or opportunities to do things better. Design is a cyclic or iterative process of continuous refinement or improvement.
9.	**Establishing need:** The process of determining the degree of need for the technological problem or solution.
10.	**Experimenting:** The process of determining the effects of something previously untried in order to test the validity of an hypothesis, to demonstrate a known (or unknown) truth, or to try out various factors relating to a particular phenomenon, problem, opportunity element, object, event, system, or point of view.

Table 7. continued

11.	**Innovating:** Taking existing "know-how" and being able to implement it in new situations.
12.	**Interpreting data:** The process of clarifying, evaluating, explaining, and translating to provide (or communicate) the meaning of particular data.
13.	**Managing:** The process of combining the basic components or ideas of phenomena, objects, events, systems, or points of view in a unique manner which will better satisfy a need, either for the individual or for the outside world.
14.	**Measuring:** The process of describing characteristics (by the use of numbers) of a phenomenon, problem, opportunity, element, object, event, system, or point of view in terms which are transferable. Measurements are made by direct or indirect means, are on relative or absolute scales, and are continuous or discontinuous.
15.	**Modeling:** The process of producing or reducing an act or condition to a generalized construct which may be presented graphically in the form of a sketch, diagram, or equation; presented physically in the form of a scale model or prototype; or described in the form of a written generalization.
16.	**Modeling and prototyping:** The process of forming, making, building, fabricating, creating, or combining parts to produce a scale model or prototype.
17.	**Monitoring data:** The process of collecting and recording data and time conditions related to problem occurrence.
18.	**Observing:** The process of interacting with the environment through one or more of the senses (seeing, hearing, touching, smelling, tasting). The senses are utilized to determine the characteristics of a phenomenon, problem, opportunity, element, object, event, system, or point of view. The observer's experiences, values, and associations may influence the results.
19.	**Predicting:** The process of prophesying or foretelling something in advance, anticipating the future on the basis of special knowledge.
20.	**Questioning and speculating:** The process of asking, interrogating, challenging, or seeking answers related to a phenomenon, problem, opportunity, element, object, event, system, or point of view.
21.	**Researching:** The process of becoming familiar with the background information necessary to investigate the problem. Knowing what type of information to look for and where to locate it.
22.	**Searching for solutions:** The process of examining multiple options when attempting to resolve technological problems.
23.	**Technology reviewing:** The process of evaluating the performance of a solution at an appropriate time in the future.
24.	**Testing:** The process of determining the workability of a model, component, system, product, or point of view in a real or simulated environment to obtain information for clarifying or modifying design specifications.
25.	**Transferring and transforming:** The process of transferring knowledge and skills across areas or fields to new situations.
26.	**Valuing:** The process of understanding the role of the technician's and other's values in deciding on courses of action.
27.	**Visualizing:** The process of perceiving a phenomenon, problem, opportunity, element, object, event, or system in the form of a mental image based on the experience of the perceiver. It includes an exercise of all the senses in establishing a valid mental analogy for the phenomena involved in a problem or opportunity.

to shift their efforts to processes of communication, visualization, representation, detailing, documentation, presentation, and modeling. In production, teachers moved from preoccupations with materials and machine-based skills to processes that cut across all material environments. The logic was that instead of the material environment dictating the material to be used, the nature of the problem to be solved ought to dictate. General lab facilities prevailed, where once a student grasped the process of cutting and shaping for instance, he or she could cut and shape virtually any material to the desired use. In addition to intellectual process of problem-solving, students would take away from the curriculum the general processes of production: bending, breaking, cutting, drilling, fitting, measuring, molding, shaping, etc. These processes turned on the more fundamental process of design.

Researchers note that the turn towards processes was generally defined by Harold Halfin in 1973. Halfin identified sixteen key intellectual processes used by designers and technologists. These processes include: operationally defining problems or opportunities; observing; analyzing; visualizing; computing; measuring; predicting; questioning and hypothesizing; interpreting data; constructing models; experimenting; testing; designing; modeling; creating; communicating; and managing. The challenge for technology teachers is one of creating activities to reinforce these processes. A process-based curriculum necessarily prioritizes process over content. Learning is not so much an issue of specific technical skills or content inasmuch as it is an issue of transferable processes. In the late 1990s, Halfin's 17 processes were expanded in the research of Wicklein and Rojewski (1999) to include a more comprehensive range of intellectual endeavors in technology (see Table 7).

Instead of expanding these intellectual processes, many design and technology educators merely focus on general technological processes. One trend is tending toward six general processes such as:

- Technology forecasting
- Creative problem-solving and design
- Research and experimentation or R&D
- Invention and innovation
- Enterprise and entrepreneurship
- Technology management
- Technology assessment

One problem of task analysis, system-based and process-based curriculum is that only certain essences tend to be identified as part of the task, system, or process. It became extremely difficult for technology educators to integrate ecological-natural, ethical-personal, existential-spiritual and socio-political content into activities and projects. Technical processes, rather than ecological, ethical, or political processes, systems and tasks dominated the curriculum. The shift back towards disciplinary content seems to resolve this dilemma by naming the ethical and political content to be studied at different levels. Another way of resolving this is to derive a curriculum from the imperatives of life in a technological world.

Universals of Technology?

Are there any universals of technology, that hold regardless of place or time? Are there universals that cut across all cultures? Anthropologists who study different cultures end up describing these cultures in an ethnocentric way. They project their own views of the world onto the cultures of interest. They see what they look for. So when they describe the cosmology of another culture, the anthropologists often group components of this cosmology into classifications that correspond to their own culture: economic, social, and technological systems for example. Similarly, it is easy to make historical assumptions that what holds now also held at all times in the past. In the anthropological instance we commit the fallacy of ethnocentrism and in the historical instance we commit a fallacy of presentism. There are differences as

Figure 7. Dimensions and content of technology

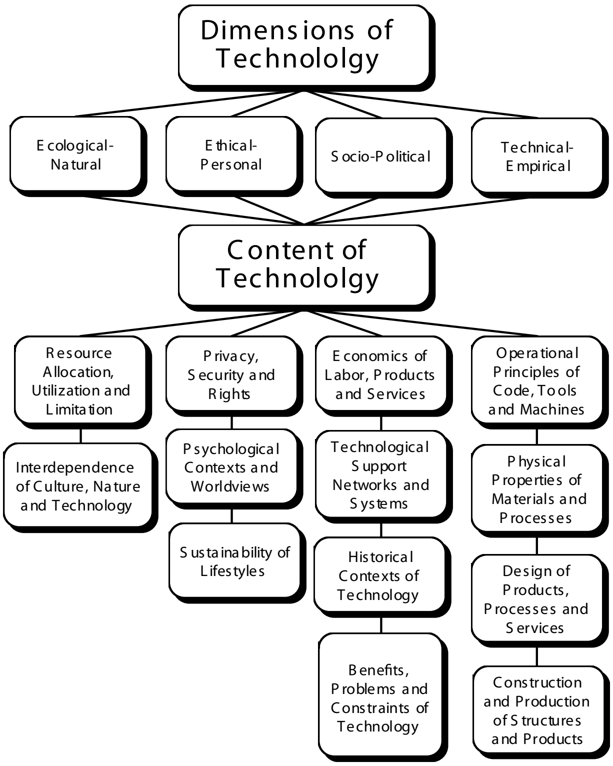


Table 8. Imperatives of technology content

Imperatives:

How can I do or make this? How was this made or done? What does this do, how does this work and how do I use it? How can I design this? How can this be fixed, maintained, or improved?

Key concepts:

Design	Design (architectural, biological, digital, engineering, graphic, interior, medical, product, urban); Principles and theory of aesthetics and function; Standards; Ideation, drawing, modeling and presentation; Animation; Experimentation and Testing; Order and planning; Cost estimate and comparison; Customization; User-centered design; Integrated and comprehensive anticipatory design; Visualization; Concurrent engineering; Product life cycle.
Materials, energy, information, process, and structure	Allocation, (re)manipulation, (re)utilization and limitation; Natural resources and synthetics; Generation and transformation of information and power; Physical, structural and aesthetic properties; Morphology; Waste reduction and removal; Media of expression; Dynamics and Statics; Material cause.
Tools and utensils, Instruments and machines	Use, efficiency and technique; Care and maintenance; Configuration and operational principles; Power and control; Quality control; Testing and Troubleshooting; Safety.
Human factors or ergonomics	Manual, mechanical and automated or cybernetic systems; Feedback; Affordance, constraint and mapping; Human-machine-artifact interface and symbiosis; Reverse engineering; prosthetics and Cyborgs; AI; Virtual reality.

Table 9.

Imperatives:

What and who was this for? Is this novel or necessary, and safe? What and whose resources were used to make this? What was the motive for making this?

Key concepts:

Subsistence, art, and utility	Survival; Luxury; Novelty; Fashion, style and taste; Minimalism; Subjectivism; Relativism; Expression and poetic license; Aesthetic and Utilitarian Judgment.
Consumerism	Consumer law and protection; Investigative media; Planned obsolescence; Marketing and hype; Human engineering; Manipulation of choice and need; Adulteration; Commodity.
Ecology	Perma-Culture; Industrial ecology; Conservation, development, scarcity, sustainability and waste; Accumulation; Pollution; Bioregionalism; Preservation and Restoration; Greenhouse effect; Green republic; Biodiversity; Biopiracy.
Consumption, convenience, capitalism, and commercialism	(Dis)information, product and labor markets; Price fixing and fluctuation; Enterprise and competition; Industrialism and urbanism; Cyberculture; Globalization.
Desire; cultural values, and identity	Symbolism; Semiotics, language and semantics; Static and Dynamic Quality.

Table 10. Creation of technology and conditions of labor

Imperatives:

Who made this? How was labor and work organized to make this? What were the conditions under which this was made?

Key concepts:

Artisanal knowledge, handicraft, and skill	Cognitive, emotional, and sensorimotor skill; Specialization; Standardization.
Occupations and conditions of labor	Division of labor; Sexual division of labor; Home, factory, office, sweatshop and open-air; Entrepreneurism; Batch and mass production; Interchangeable parts; Assembly line, mechanization and automation.
Organization of labor, technology, and work	Labor market; Job content and design; Skills and training; Economic sectors; Occupational health and safety; Discrimination and harassment; Power.
Management and unionism	Bureaucratic structure; Scientific management; Time, motion and fatigue; Total Quality; Participatory management; Labor relations.
Industry and labor	Distribution of work and income; Centralization; Productivity; Capital; Alienation; Exploitation and imperialism; Colonialism; Globalization.

Table 11.

Imperatives:

What was used before this? Who developed and who used this? What happened?

Key concepts:

Technological change	Technological evolution and cumulative change; Invention, development, innovation, diffusion; Social construction of technology; Social and cultural selection; Technoscience.
Historical continuity and social change	Serialization; Anecdote; Human agency and intentionality; Contingencies; Technological determinism; Autonomous technology; Dialectical materialism.
Interaction of technology, culture, and nature	Biodiversity; Extinction of species; Green house effect; CFCs and ozone layer; Interdependence of science, technology and nature; Technological system; Research laboratories; R&D; Intellectual property rights; Copyright, trademark and patent systems; Actor-network theory; Complexity and chaos theory; Commodification; Reification.
Technology, class, gender, race, and sexuality	Harassment; Sexism; Racism; Environmental racism; Masculinity; Sexual division of labor; Emotional labor; Reproductive labor; Patriarchy; Oppression.
Military- industrial-academic complex	Networks; Collectives; Cyborgs; Patent system; Science, technology and the military; Political Ecologies; Complicity; Concentration of Power; Secrecy; Intelligence; Propaganda; Militia; Weapons systems; Procurement; Terrorism; Military-Industrial Complex; Imperialism; Empire.

Table 12. Making, using, and working technology

Imperatives:

Is there a better way of making, using and working? What are the options?

Key concepts:

Praxiology and mechanology	Economization of energy, time, materials, terrain and apparatus; Precision; Efficiency; Functionality; Durability; Speed; Skill; Ingenuity; Method; Working plans; Engineering Sciences (Statics and Dynamics).
Technophilosophy	Functionalism; Technocracy; Biomorphic and organic design; Bauhaus, Dymaxion (Buckminster Fuller) and Usonian (Frank Lloyd Wright); Utopianism; Science Fiction.
Forecasting and assessment	Input-output; Cost-benefit; Systems analysis; Trend extrapolation; Dynamic modeling; Hazard; Risk; Higher order consequence; Technological forecasting; Technology assessment; Disclosive analysis.
Appropriate or intermediate technology	Polytechnics and monotechnics; Anatechnology and catatechnology; Local knowledge; Decentralization; Technology transfer.
Cyberculture	Cybernetics; Networks; Collectives; Cyborgs; Cyberspace; Cyberpunk fiction; Virtual reality; Cyborg democracy.
Philosophies and theories of work and technology	Workplace democracy and profit sharing; Technology Bill of Rights; Technological "progress"; Neo-Luddism; Feminist technology; Democratic and autocratic technology; Civilizing, democratizing or humanizing technology; Constructive technology assessment; Distributive justice and wealth; Marxism; Frankfurt School; Hybridity; Human Rights.

well as commonalties across cultures and time. The challenge is to remain sensitive to both while refraining from asserting that dimensions or systems of technology are universal. The content or content organizers of any discipline or subject are not universal. They are contingent on a culture at particular points in time. In technology, there are no universal dimensions or systems. There are, however, dimensions and systems that gain a consensus at points in time (Figure 7).

This book asserts that at this point in time, the ecological-natural, ethical-personal, existential-spiritual, socio-political and technical-empirical dimensions of technology are the most effective to use in C&I. The alternative organization of content provided in the previous section was derived from these dimensions

Imperatives of Technology Content

In the disciplinary organizations of technology created in the 1960s, content was organized around economic sectors of technology (e.g., communication, produc-

Table 13. Change and technology

Imperatives:

What will help me to change how things are made and used, and who participates in technology? Who's in Charge?

Key concepts:

Critical regard and activism	How things work; Do-it-yourself; Access to information; Community Initiative; Act locally--think globally.
Grass roots and regulatory action	Science, Technology and Workplace Policy; Environmental and social policy; Investigative initiative and media.
Quality of Life	Human rights; Dignity of work.
Feminist and multicultural critiques	Access; Equity; Equal pay for equal work; Glass ceiling; Emotional labor; Cyberfeminism; Performativity; Postcolonialism; Gender studies; Globalization.
Cyborg agency	Monkey wrenching; Short circuiting; Culture Jamming; Machine ontology; Resistance.

Table 14. Lifestyle and technology

Imperatives:

Where do I begin with my lifestyle?

Key concepts:

Simplicity, modesty, and frugality	Sustainability.
Rights	"Natural" rights; Constitutional rights; Animal rights; Human rights; Disability rights; Gay and lesbian rights; Aboriginal rights; Environmental rights; Ontology; Majoritarian and Minoritarian rights; Limits; Privilege; Intellectual Property.
Vision	(Re)enchantment of nature and technology; Spirituality.
Artistic expression and political statement	Modernism; Realism; Dada and Futurist movement; Bauhaus; Performance.
Activism	Politics.
Ethical standards and moral strength	Prudence; Virtue; Whistle-blowing; Sensibility, Dignity and Compassion; Ethics and morality.

tion). In the most recent disciplinary organization in the standards project, content is organized around conceptual branches of technology (i.e., information, physical, biochemical) and technological processes (e.g., design, developing, utilizing and managing systems, assessing consequences). Alternatively, the content of technology can be organized around the imperatives of technology (i.e., cultural, ecological, ethical, practical, etc.). The structure that follows organizes content around imperatives in a general order from practical, cultural, economic, psychological and social imperatives to ethical imperatives (Petrina, 1998). This alternative organization of content in technology studies moves from the problem of how things work to the problems of how things work for some but not others and who's in charge?

The organization begins with what is often an innocent query of children and adults: How can I make this? The premise is that, eventually, through sustained questioning, practice, and study, students will develop more meaningful and complex understandings of technology, and toward the ends of the technology curriculum—critical technological sensibility and political action or literacy and capability. This outline derives content from four interdisciplines of technology studies (design, practice, studies, and criticism). In the elementary grades, the lower tiers of the organization of content would dominate and determine the curriculum. The middle years and high school curriculum would take on the middle and upper tiers of the outline. The outline goes well beyond the schools however, and continues through to adulthood, where we come to terms with the sociology and philosophy of technology and the active pursuit of ethical justice in technology.

Projection and Reflective Practice

This chapter and the last made the case that the content of technology studies is the primary justification for including the subject in the schools. This chapter began by acknowledging that there are three general sources of content: individuals, culture, and nature. Technology studies has drawn from all three of these sources but the trend is toward cultural sources, namely disciplinary content of technology. The trend is toward an inclusive discipline and technological pluralism. The ISTE's and ITEA's technology standards projects represent the latest attempt to develop consistent disciplinary content and standards for technology studies. A vast majority of technology educators feel that the standards projects are timely endeavors. In most cases during the last century, there was little consistency among schools and across provinces and states. Technology teachers had the liberty to teach whatever they wanted. There was little, if any, accountability. Content and standards derived from a coherent discipline are signs of maturity in technology studies. Without consistency and accountability, technology studies has little chance of becoming a subject required of all students, K-12. In this chapter, we also elaborated on conceptual analysis and task analysis, two methods used for deriving content. We addressed the challenges of processes as content models of curriculum, which represent attempts to merge conceptual and task analysis. In this chapter, the emphasis was on the question "what should be learned?" This next chapter focuses on the question "how should it be organized for teaching?" Both chapters provide an introduction to curriculum design and theory.

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Chapter IX

Curriculum and Instruction Design

Introduction

Who should design the curriculum that technology educators teach? Should curriculum be developed by governments and ministries of education? Should curriculum design be privatized and limited to commercial vendors? Should teachers design their own curriculum? Who should design the instructional materials? Should all materials be professionally designed by a vendor? As we noted in the previous chapter, technology teachers have had a century of freedom in designing and customizing their curriculum and instruction to suit themselves, their community, or the students. This had its advantages in diversity. The disadvantages, as we noted, related to the inconsistencies from school to school, even in the same district. When the teacher departed from a school, he or she typically departed with the curriculum and instructional materials. New teachers often began their first school year with little more than what they carried with them from their teacher preparation programs and student teaching experiences. One major problem was that when it came time for governments to identify priorities in the schools, technology studies was overlooked because of its incoherent curriculum. As indicated in Chapter VIII, the international trend is quickly shifting toward standards and unified curriculum in design and technology—the trend is toward a consistent scope and sequence of content for the study of technology. Common curriculum and goals along with content and performance standards are the trends. From a perspective of professional vitality and political finesse, these trends are healthy. These trends offer the potential for long-term sustainability of technology studies in the schools. Nevertheless, given that all curricula are fallible and have shortcomings, teachers will always have a need for dispositions toward, or skills and knowledge in, curriculum and instructional design.

The questions "what should be learned?" and "how should it be organized for teaching?" are eventually resolved, whether by consensus, fiat or might, through processes of *curriculum and instructional design*. One is basically a question of content, the other a question of form. Neither can be resolved without changing the other—the questions are dialectically related. We can say that curriculum and instructional design involve the forming of educational content and the contents of educational forms. Curriculum theorists take it for granted that curriculum flows from the "*what*" of "what should be learned?" Instructional designers take it for granted that instruction flows from the "*how*" of "how should it be organized?" Theorists neglect design. Designers neglect theory. Teachers, however, cannot afford to neglect either theory or design; they have to be theorists and designers. In this chapter, curriculum and instructional design are explained along with a focus on the design of projects, units, and modules. This chapter combines background knowledge with techniques of curriculum and instructional design. The chapter concludes with sections on course design, copyright, and academic freedom. In some of the previous chapters, the emphasis was on "what should be learned?" This chapter focuses on "how should it be organized for teaching?"

Curriculum Design and Theory

The practice of organizing curriculum—activities, environments, goals, knowledge, student and teacher interests, social conditions, technologies, values and the like—into a containable pedagogical form involves a series of judgments. Judgments are necessarily made on what and whose knowledge is of most worth, the scope and sequence of this knowledge, how student desires will be focused, what technologies to deploy or purchase and so on. Curriculum designs lend form to, and chart provisions for, the processes of learning and teaching and become concrete and operational at various stages of educational practice. The very nature of student experiences are shaped by the way we choose to design, or not design, curriculum. In other words, different curriculum designs provide varied qualities and powers of experience and knowledge. Curriculum design might at first glance appear to be about the economics and pragmatics of teaching, about arranging content and assignments, apportioning time on timetables, and allocating resources. Curriculum is, and is much more than, scope and sequence. Mundane *and* profound judgments are made when we plan, shape and judge human experience. Congruence between educational outcomes and curriculum documents is virtuous; but when curriculum design is seen as the moral and political endeavor that it is, the issue takes on deeper significance.

What should be learned? How ought it be organized for teaching? *Curriculum design* involves a form into which curriculum is cast or organized. Curriculum is generally organized through designs such as: Disciplines (e.g., mathematics, engineering, humanities, sciences); Fields (e.g., art, civics, design, home economics, industrial arts, social studies); Units (e.g., bicycling; child labor; feminism, jazz; mass media; queer fiction; verbs; water colors); Organizing Centers (e.g., activities, modules, minicourses, problems, processes, projects, tasks and competencies); or Personal Pursuits (e.g., aerobics, autobiography, cooking, bird watching, guitar playing). Core or Interdisciplinary designs employ combinations of disciplines or broad fields (Petrina, 1998). Disciplinary, field, and interdisciplinary designs typically employ units and organizing centers to engage students in pre-structured knowledge. Here, problems and units are developed to establish understandings of organized bodies of disciplinary knowledge. Curriculum designs are generally selected for their powers in bolstering political causes and conferring political status, and since the early 1960s, disciplinary designs have been politically valued over the others. High school humanities and sciences employed disciplinary designs in the early 1960s to secure economic and liberal roles. Projects and units conferred a progressive status in the 1910s and 1920s for newcomers in the school curriculum such as industrial arts, audio-visual education, and social studies. Just as teaching methods are associated with different theoretical "families," curriculum designs have theoretical orientations.

A consensus in curriculum theory formed around five orientations to organizing curriculum: academic rationalism, cognitive processes, self-actualization, social reconstruction, and utilitarianism (Eisner & Vallance, 1974). Academic rationalist orientations are primarily about disciplinary knowledge and cultural canons. Cognitive process orientations are primarily about intellectual reasoning skills such as problem-solving. Self-actualization, or personal relevance, orientations stress psychological conditions and are concerned with individuality and personal expression. Social reconstruction, generally called critical pedagogy, stresses sociological conditions, social justice, and collective reform. Utilitarian orientations are primarily concerned with functional competencies, performance, procedure, and instructional efficiency. Curriculum designs are conceptually grounded in any one or a mix of these orientations. In 1992, a special issue of the *Journal of Technology Education* was published to explore each of these five designs (see Herschbach & Sanders, 1992). A basic conclusion from this is that generic, neutral theoretical orientations and designs for organizing curriculum simply do not exist (Beyer & Apple, 1998; Eisner, 1979; Herschbach, 1989; Pinar, Reynolds, Slattery, & Taubman, 1996; Zuga, 1989).

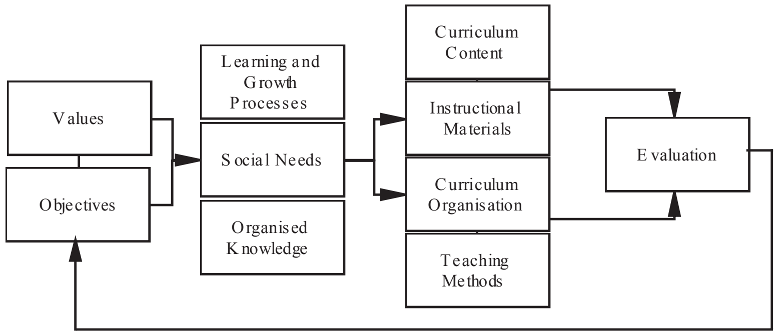
Other theorists conclude that there are three basic orientations to curriculum—transmissive, transactive, and transformative curriculum or technical, practical, and emancipatory curriculum. If we can hold off on ranking these, there is great value in theorizing transmissive, transactive, and transformative orientations to curriculum. In fact, teachers can be quite empowered by the knowledge and skills in designing curriculum that is at times transmissive, and other times transactive or transformative. A transmissive orientation typically means that information is transmitted from teacher to students. For example, safety procedures are best taught from a transmissive orientation. Here, the teacher simply has to say "pay attention, this is the way it is done—step 1 through step 6." A transactive orientation typically means that the question "what should be learned?" is democratically negotiated. Here, the teacher may work with small groups and say: "Let's discuss your ideas for how we should handle this situation." In a transformative mode, the teacher provides content and methods that are truly empowering for the students. For example, the teacher may provide a civil liberties lesson that empowers the students to take advantage of their freedoms of speech in a zine or on a Web site. There are times when teachers consciously ought to be transmissive and other times when they ought to be in a transactive or transformative mode. The key is to know and recognize the difference in designing curriculum.

Theorists also note that distinctions are made among the overt or taught curriculum, covert or hidden curriculum, null or untaught curriculum, and evaded or taboo curriculum. The detrimental, mixed, and unintended effects of technology are typically part of the evaded curriculum while technoenthusiasm is prevalent in the taught curriculum. Critical theorist Michael Apple (1993) notes that the taught curriculum, and often the hidden curriculum, represent "official knowledge," relegating everything else to taboo and unofficial knowledge. Most vendor-produced materials and textbooks used in the schools reinforce the official knowledge of the curriculum. Many teachers nevertheless assert their professional judgment and academic freedom to select from the null and evaded curriculum to design materials that provide a venue for introducing "unofficial knowledge to students. This is one of the reasons why curriculum and instructional design are so important to teachers.

In 1949, Ralph Tyler summed up centuries of curriculum design into four simple steps. For Tyler, the process of curriculum design amounted to a way of resolving four questions, or a rationale:

1. What educational purposes should the school seek to attain?
2. How can learning experiences be selected which are likely to be useful in attaining these purposes?
3. How can learning experiences be organized for effective instruction?
4. How can the effectiveness of learning experiences be evaluated?

Figure 1. Model of the curriculum design process



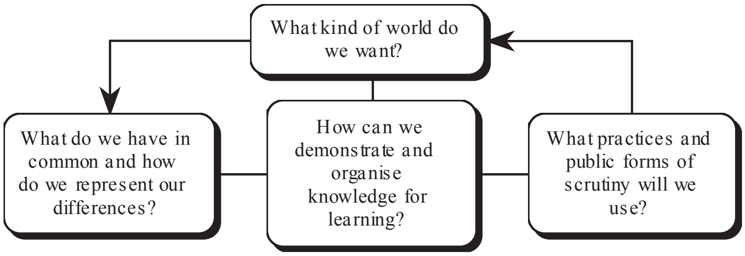
In the 1960s, curriculum designers such as Hilda Taba (1962) reduced Tyler's curriculum rationale into a simple procedure:

1. Diagnosis of needs
2. Formulation of objectives
3. Selection of content
4. Organization of content
5. Selection of learning experiences
6. Organization of learning experiences
7. Determination of what to evaluate and the ways and means of doing it

This procedure has defined curriculum design since that time. Curriculum design became little more than a determination of goals, activities, content, delivery systems, and assessment techniques. Curriculum design became basically little more than an exercise in solving a series of problems (Figure 1).

Rather than a technical procedure of writing objectives, choosing activities, content and methods and modes of assessment, curriculum theorists in the mid to late 1970s pointed out that curriculum design involves extremely important questions about the world. Each time that teachers purchase educational software, a textbook, wood for carpentry or software from a vendor, they are addressing questions about what kind of student and world they want. Each time that teachers assign a project, design an activity or curriculum materials they address these questions. Currently, theorists remind us that the simple questions "what should be learned?" and "how should it be organized for teaching?" are quite complex and political. They caution us to think carefully about the decision we make on behalf of curriculum design. Curriculum design now involves a rationale with a greater moral weight than Tyler's of the 1950s (Figure 2) (Petrina, 2004).

Figure 2. Critical design of C&I



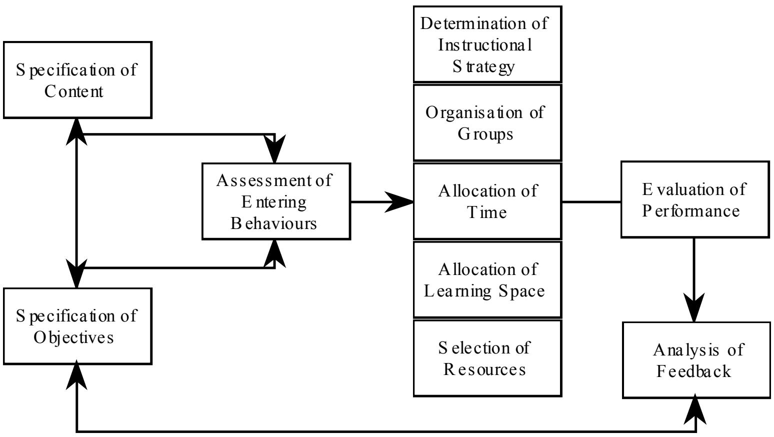
In the next section, the background and process of instructional design is explained. Subsequent sections deal with projects, units, and modules. The intent is to move from theory to procedure to practice as this chapter progresses.

Instructional Design and Theory

In the 1950s, generally when *instructional design* (ID) was established from a field of media specialists, educational psychologists and industrial and military trainers, instructional designers shrank Tyler's rationale to fit the act of instruction—the rationale was tailor-made for C&I (Figure 3).

Unable to completely identify with Tyler's rationale, instructional designers contrived an ID rationale:

Figure 3. Model of the instructional design process (Adapted from Petrina, 2004)



1. For whom is the program developed? (characteristics of learners or trainees)
2. What do you want the learners or trainees to learn or demonstrate? (objectives)
3. How is the subject or skill best learned? (instructional strategies)
4. How do you determine the extent to which learning is achieved? (evaluation procedures)

And similar to Taba's simplification of curriculum design, instructional designers reduced ID to a simple procedure of instructional systems design (ISD): A cybernetics system with five pases (analyze, design, develop, implement and evaluate), In effect, ID is basically the same as curriculum design. If there is a difference between curriculum and instructional design, it is that curriculum designers place more of their stock in the question "what should be learned?" while instructional designers emphasize the second question, "how should it be organized for teaching?"

Both curriculum and instructional design prompt us to think *ecologically* and *systemically* about C&I, as mentioned in Chapter IV. Systems involve energy, relationships, conditions, generative processes, causes, effects, and reciprocal feedback. Ecologies involve interdependencies and Webs of exchange. When we design an instructional system or ISD we also necessarily design a learning system. When we design curriculum we also design instruction. When we focus on content we also focus on form. Designers, including the best designers of products or images, are quite adept at tuning C&I into particular components of ecologies or systems while minding the wider spectrum of processes and relationships that characterize the system. They are able to focus and keep their mind on the big picture—at the same time. The same is demanded of educational designers. Teachers and teacher educators tend to focus in on teaching and the performance of teachers at the expense of attending to students and learners. Curriculum designers tend to focus on content and instructional designers on form or process, neglecting the larger picture. The great contribution of curriculum design, ID and ISD are well-articulated and empirically-tested principles that help us focus and keep our minds on details *and* the big picture—at the same time.

Principles of Curriculum and Instructional Design

C&I design is effective when principles of design, such as accessibility and equity, are consistently followed and deployed. While guidelines and principles of C&I design are quite simple and specific, they are often neglected in practice. In teacher education, students often wonder how professors can so readily talk about the importance of principles while neglecting the principles in their own classrooms, materials, and activities! Park and Hannafin (1993), Hashim (1999), Mayer (1993), and Sherry (1996) developed principles and corresponding applications for design-

Table 1. Principles for designing interactive media (Adapted from Park & Hannafin, 1993)

Principle	Principle
1. Related prior knowledge is the single most powerful influence in mediating subsequent learning.	11. Knowledge flexibility increases as the number of perspectives on a given topic increases and the conditional nature of knowledge is understood.
2. New knowledge becomes increasingly meaningful when integrated with existing knowledge.	12. Knowledge of details improves as instructional activities are made more explicit, while understanding improves as the activities are made more integrative.
3. Learning is organized by the supplied organization of concepts to be learned.	13. Feedback increases the likelihood of learning response-relevant lesson content, and decreases the likelihood of learning response-irrelevant lesson content.
4. Knowledge to be learned needs to be organized in ways that reflect differences in learner familiarity with lesson content, the nature of the learning task and assumptions about the structure of knowledge.	14. Shifts in attention improve the learning of related concepts.
5. Knowledge utility improves as processing and understanding deepen.	15. Learners become confused and disoriented when procedures are complex, insufficient, or inconsistent.
6. Knowledge is best integrated when unfamiliar concepts can be related to familiar concepts.	16. Visual representations of lesson content and structure improve the learner's awareness of both the conceptual relationships and procedural requirements of a learning system.
7. Learning improves as the number of complementary stimuli used to represent learning content increases.	17. Individuals vary widely in their needs for guidance.
8. Learning improves as the amount of invested mental effort increases.	18. Learning systems are most efficient when they adapt to relevant individual differences.
9. Learning improves as competition for similar cognitive resources decreases, and declines as competition for the same resources increases.	19. Metacognitive demands are greater for loosely structured learning environments than for highly structured ones.
10. Transfer improves when knowledge is situated in authentic contexts.	20. Learning is facilitated when system features are functionally self-evident, logically organized, easily accessible, and readily deployed.

ers of C&I. The principles are derived from a synthesis of research into cognition and learning. Use these general and specific principles as guidelines for designing activities, demonstrations, modules, projects and units.

Evaluating C&I Products

In the first half of the book, we explained theoris that underwrite the adoption, design, or creation of C&I materials, such as overheads, videos, and manipulatives. In the first and second chapters, we emphasized the goals of formal communication, noting that the materials and resources you create and use reflect on your professionalism. Visuals (images, text, etc.) play an essential role in the communication of both procedural and propositional knowledge. Visuals reinforce our demonstrations and the image our students develop of the demonstrator. In Chapter IV, we noted that an additional reason to create effective visuals relates to the accommodation of different learning styles. Some students are visual learners. In Chapter VI, we elaborated on how visuals and manipulatives are supported by learning theories. For example, Dale's Cone of Experience arranges the three major modes of learning (Enactive (direct experience), Iconic (pictorial experience), and Symbolic (highly abstract experience) into a hierarchy. This helps us to understand the interrelations among the three modes. They reinforce each other. We did not, however, address the evaluation of C&I resources, or the criteria that teachers use for adoption.

Criteria for evaluating products of C&I are divided into four categories: Content, Instructional Design, Technical Design, and Ecological and Social Considerations. There are also additional media-specific criteria. Teacher-evaluators must be aware of general learning resource considerations in these four general areas. There are two primary dimensions to the evaluation of C&I materials. The first is the policy dimension. Most educational ministries or governments, and local school districts, have policies in place for the creation and adoption of materials and resources. Some policies are overly restricting, placing limits on the professional judgment of teachers. There may be a list of "approved" resources—everything else may require special approval *via* special forms. Vendors are submitted to policies similar to teachers. Other policies merely maintain the standards of copyright law and licensing. And still others are constructive. Within the first week or two of student teaching or employment, it is important that teachers become aware of their school's policy on adopting and creating curriculum materials. The second dimension in the evaluation of C&I materials is practice. We need to develop a certain level of connoisseurship for making decisions on the C&I materials we adopt or create. This has a special significance in the context of digital media and technology products and projects. The following general considerations for selecting Web sites ought to be considered.

Teacher-Evaluators must consider the wide range of students that are represented in the average technology class, as well as those that are not represented. This means that teachers model respect for all groups regardless whether or not they are represented among the immediate group of students. Special considerations in technology studies include the first language of the students, gender, and the existence of special needs. These issues will be addressed in Chapter XI. The purpose, characteristics, and use of various media—print, video, and digital formats—also demand special criteria. In technology, as we will explain in Chapter XI, there are various considerations for applications, architecture, devices, materials, machines, manipulatives, and various products designed, purchased, and used. There is a significant incentive (e.g., access, ecology, flexibility) to adopt and create digital materials for C&I (Hashim, 1999; Mayer, 2003). Specific criteria apply to the evaluation of digital materials, in addition to our general criteria. An example of digital resources evaluation form from British Columbia is provided below (BC MOE, 2000). Given what we know about digital and instructional design, the following general considerations for selecting Web sites ought to be considered.

Reliability/Validity Considerations

- Clearly indicate author, contact information, latest revisions/ updates, and copyright information.
- Distinguish between internal links to other parts of the resource and external links that access other resources.
- Reflect an author, designer, or publisher with a credible reputation.
- Where any information is collected, the site has a stated privacy policy.

Content Considerations

- Support curriculum outcomes.
- Include, where appropriate, works of local producers.
- Have relevance to students' lives and interests.
- Include adequate information to judge the accuracy of factual or historical information
- Present information logically.
- Present information of sufficient scope and depth to cover the topic adequately for the intended audience.
- Model correct use of grammar, spelling, and sentence structure.

Audience Considerations

- Promote individual or group interaction as appropriate.
- Provide for a variety of reading levels, language abilities, and multilingual capabilities, as appropriate.

- Provide content that is appropriate for the intended age, grade level, and classroom demographics.
- Present information in a manner that stimulates imagination and curiosity.
- Provide interaction that is compatible with the physical and intellectual maturity of the intended audience.

Social Considerations

- Ensure material is appropriate in terms of:
- Gender equity/role portrayal of the sexes.
- Portrayal of sexual orientation.
- References to belief systems.
- Age portrayals.
- Socio-economic references.
- Political issues bias.
- Regional bias.
- If applicable, ensure product advertising is not intrusive.
- Present information in an objective, balanced way, including alternative perspectives.
- Multiculturalism and anti-racism content.
- Aboriginal culture/roles.
- Portrayal of special needs.
- Ethical/legal issues.
- Language use.
- Portrayal of violence.
- Safety standards compliance.

Projects

Projects have characterized technology studies from its earliest days. Historians note that projects date to 16th century Italian architects, who had their students devise elaborate plans of public buildings and churches, most of which could not be built. French engineers in the 18th century and American mechanical engineers in the 19th century adopted a similar practice, but required students to actually produce the machine parts they drafted. The first manual training high school in the U.S., founded by Calvin Woodward, brought the project method into the schools. For Woodward, projects were supposed to be "synthetic exercises," culminating particular steps in a student's progression through manual training. Woodward argued instruction should progress from elementary principles to practical applications, through projects. In his terms, students, *via* projects, should progress from instruction to construction. Dewey disagreed with Woodward on an important point. Dewey argued for a psychological rather than logical order to projects. Rather than derived logically from instruction, Dewey's projects were derived psychologically from the student. In other words, Dewey thought that projects should derive from the students' interests rather than from the logic of the steps on instruction (Knoll, 1997). For Dewey, rather than a vehicle for the exercises of skill development, the project was a vehicle for bringing the spirit and conditions of modern life into the school. Technology educators have inherited the two approaches, and for most of the 20th century, they valued the project as a vehicle for skill development *via* logical steps of instruction over Dewey's notion. This led to the notion of the project as a product or thing to be developed. Contrary to this, Dewey reminded us, the project serves as a method of instruction for disclosing the workings of life, as noted in Chapter VI. The common theme of projects was the *unity* within the students' heads, hearts, hands, and feet. This unity is what makes a project a project. What is a project? What are the advantages and guidelines for an adequate or educational project?

What is a Project?

- A project is a method whereby students work through a series of activities and problems culminating in the completion of something tangible (e.g., artifact, media, performance).
- A significant, practical unit of activity of a problematic nature, planned and carried to completion by the student in a natural manner and involving the use of physical materials to complete the unit of experience. A project is the solution of problems on the real plane of activity (Bossing, 1942).

Advantages of Projects

- Projects serve as a vehicle to understanding key principles and concepts as well as to the development of dispositions.
- Projects place students in realistic, problem-solving environments.
- Projects can build bridges between school and other life experiences. The problems resolved in the pursuit of a project are valued and shown to be open to systematic inquiry.
- Projects require an active and sustained engagement over extended periods of time.

- Projects can promote links among disciplines and can erode subject boundaries.
- Projects are adaptable to a wide range of student interests and abilities.

Guidelines for Projects

- The project is not merely the thing. It is also a method and process.
- Projects must have definite educational values as directed by ecological and social values.
- Intrinsic values ought not override the purpose of the project as a method. (Do not be overly persuaded by the students' desires).
- Projects should be situational or relevant to the students and the context.
- Projects should serve as a vehicle for disclosing the conditions and processes of modern technology, or content of technology.
- The time consumed must be commensurate with the values that accrue from execution of the project.
- To be educational, a project "must be of such a nature as to offer a large opportunity, not only for the acquisition of new skill, and experience" but also in the application of new concepts (Sneddon, 1916, p. 421).

Ideally, students should pursue projects that involve non-trivial problems requiring sustained attention. In most cases, the outcomes of a project cannot be fully fixed from the outset, or the process will be overly restrictive. Projects typically culminate in an artifact, media or performance that relate to the original purpose. The artifacts and media range from digital images and text to three-dimensional models, drawings, paintings, sculptures, songs, and useable products. The issue of the functional, useable artifact has nagged technology teachers for over a century. Some technology teachers continue to argue that students must take a tangible artifact home. The value of the process is invested in the artifact. This has its place in technology studies, but the trend is to moderate this emphasis by focusing on the process rather than the product. In many cases, the project became an end in itself and was the sole purpose for the unit, course, or group of courses. The product overshadowed the value of the process. After the completion, the product was assessed for quality. For example, in a woodworking course in industrial arts, a clock or table would be assessed and given a mark. In information technology, an image would be created and assessed. Technology teachers lost sight of the potential of projects to, as Dewey noted, bring into the school the conditions and processes of modern technology. Of the two extremes described, the project as vehicle for the exercises of skill development was valued over the project as a vehicle for bringing the spirit and conditions of modern life into the school. However, this is changing.

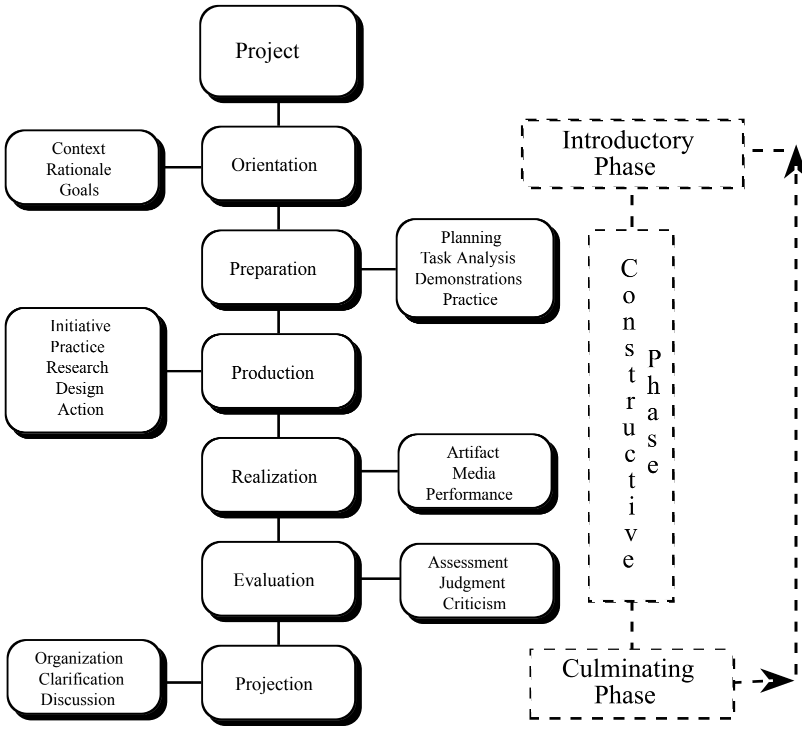
One difference between technology studies and industrial or audiovisual education or computer engineering is the emphasis placed on the project. Technology teachers began to shift their emphases in the 1980s and 1990s toward Dewey's original notions of the project as a vehicle for disclosing the workings and conditions of everyday life (see Chapters V-VI, VIII). This could mean the use of a project to disclose mathematical or scientific principles underlying a particular technology as well as the social conditions underlying how workers use that particular technology. This trend toward the refocusing of the project in technology studies from product toward process cannot be overstressed. The bulk of projects in technology studies ought to be vehicles for disclosing a range of content. Their purpose must be driven with this in mind. Of course, most projects will, and ought to, provide for the expression and development of creativity, but this purpose is secondary to the disclosure of content. Projects continue to be extremely important in technology studies, but their purpose has been refocused.

Projects have a coherent curriculum form that progresses through the stages established nearly a century ago (Figure 4). Today, the form of projects is very similar generally based on Kilpatrick's form of purposing, planning, executing, and judging. Projects should be designed so that instruction progresses through introductory, constructive, and culminating phases. If any of these are skipped, the project is incomplete. However much projects are characterized by student initiative and production, they are extremely instruction-intensive. To make a project work, teachers do a considerable amount of planning and behind-the-scenes management. Teachers have to time their demonstrations to coincide with particular tasks in the project. Some teachers prefer to front-end the demonstrations and skills, but invariably find themselves doing various just-in-time demonstrations as well. Ultimately, there has to be a realization of the artifact, media or performance. And with the realization ought to come assessment, criticism, and judgment. When it's all said and done, the teacher has to step back and help the students organize the content of what was learned.

Design projects take a similar form, although it is expressed differently (Figure 5). The progression begins with an emphasis on conditions—the conditions of the world, the local scene, and of needs, wants and desires. The second phase is constructive and results in an expression of forms in tandem with an interpretation of this expression. Interpretation and expression go hand in hand. The process is culminated with a public critique. Design processes were detailed in Chapter V.

Projects cause a considerable amount of anxiety for technology teachers. Teachers have been known to panic over what projects to incorporate into the curriculum. Some teachers feel that without an adequate number of projects there can be no curriculum. Anxiety leads to choices of products that compromise the subject. Instead of asking what content can serve this project, technology teachers are now asking what projects can serve this content. The order of priority has toggled 180 degrees. The project is no longer the thing. The project is a method for disclosing content.

Figure 4. Instructional design principles



Units

In the mid 1920s, Henry Morrison (1926, 1931) combined the initial notion of unit (i.e., unit of experience) with disciplinary notions for his practices in the secondary

Figure 5. Design project model

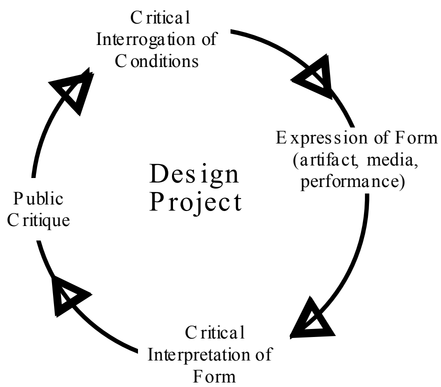
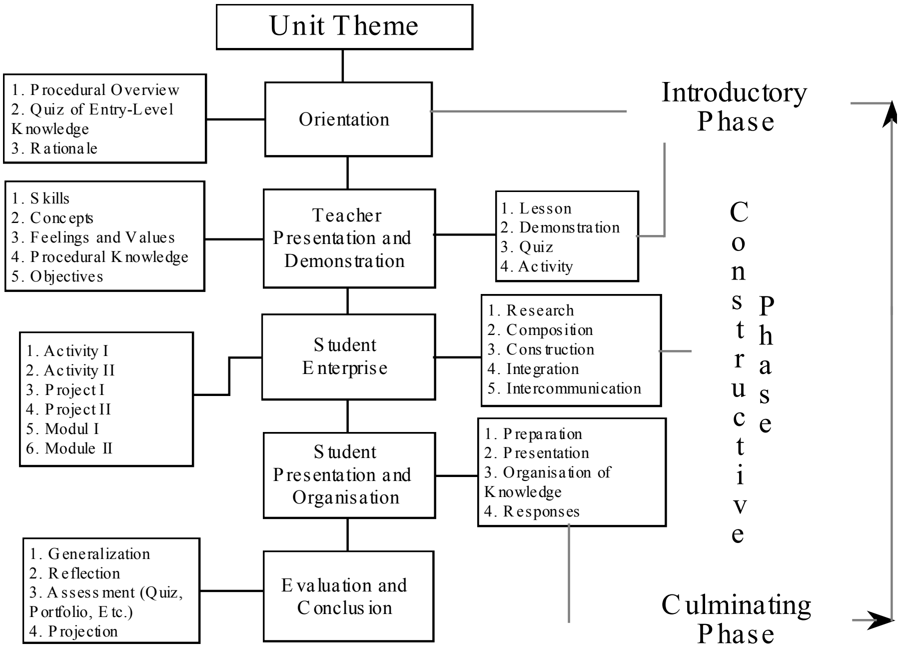


Figure 6. Unit model



school at the University of Chicago. He defined a unit as a large block of related subject matter, which provided a theme, combined with activities, problems, and projects over several weeks to generate understandings of the theme and related knowledge. For example, Morrison used themes such as the French Revolution in history, and the Earth as a Planet in science.

Units for technology studies are combinations of the project method and Morrison's method—units progress from an introductory phase through constructive and culminating phases. A unit is *not* merely a collection of activities that relate to disciplinary subject matter. The intention is to allow for depth while at the same time a breadth in different areas. A unit is an intentionally designed, integrated, thematic organization of curriculum and knowledge involving combinations of demonstrations, discussions, activities, modules, problems, and projects (Figure 6).

Units in technology involve a holistic integration ecological-natural, ethical-personal, existential-spiritual, socio-political and technical-empirical aspects of tools, machines, information and software, instruments and processes, or technologies. A course should involve units that are broad in scope, where each unit provides a depth in content while focusing on larger themes. Units can be anywhere from three days to three months. They should involve a variety of activities, where some activities extend over more than one day. Units typically mean that existing activities or technical skills are "contextualized," or cast into a larger frameworks to provide unity.

Table 2. Essential characteristics of a unit

1.	It has wholeness and coherence across activities, modules, projects, lessons, etc.
2.	It transcends subject matter boundary lines and provides for the integration of subjects.
3.	It contains short and long-range objectives and learning experiences.
4.	It provides a wide range of methods adaptable to learning styles.
5.	It draws from current information as contrasted with textbooks containing information that may be dated.
6.	It promotes cooperation, democratic planning, and a wide range of insights. It is unified.

The determination of the types of units designed is typically up to the teacher, who must fulfill responsibilities to the larger structures of content, courses and government dictates. Of course, as in the case of projects, students ought to have input into the process designing the unit. Units are typically broadly conceived to accommodate individuality. Technology units for a high school group could conceivably be organized as: technology and rights; mass production; digital animation; energy, environment, and personal consumption; old materials, censorship and digital expression; communicable disease and modern medicine; or apparel, fashion and style.

The key to a unit is planning. The most effective units entail a great amount of planning. Remember, the scale of curriculum increases as one moves from lesson plans and demonstrations to activities, modules and projects and ultimately to units and courses. A unit plan is actually a collection of resources for the teacher and students. A unit plan allows the teacher to proceed with confidence and foresight. The unit format provided below is comprehensive and recommended for planning. In general, the unit plan is a blueprint and provides the rationales, semantics, logistics, scope, sequence, and resources for the initiation and completion of the unit. Typically, a planning grid accompanies the unit plan and serves as the daily work order for the unit (Table 4). Many teachers trivialize a unit by merely collecting a bunch of resources, collating them, and calling them a unit. Or, teachers organize the scope and sequence of content and call this a unit. But units are much more than this, especially in technology studies and other experience-based subjects. We have to take C&I design seriously and unit plans help us to do this. Our units, and our projects, ought to look like the model explained earlier in Figure 6.

Normative Units

The "normative unit" was developed in the 1950s to provide a framework for dealing with controversial issues (Chapter IV). The form of a normative unit is derived

Table 3. Unit plan format

Title: Choose a thematic, encompassing, and personally relevant title.

Rationale and ends: Why is a study of the technologies in this unit relevant to the students? This section refers to relevance to the students lives, NOT merely relevance to government curriculum documents. How will the technologies relate to the ecological-natural, ethical-personal, existential-spiritual, socio-political and technical-empirical dimensions of technology? What are the major goals and objectives? (1 page of context and goals).

Outcomes: List the objectives or intended learning outcomes. Include a balance of affective, cognitive, and psychomotor objectives and outcomes. Consider alternative and various ways of teaching. These ought to relate to the assessment schemes. Include these in the planning grid.

Outline of content (scope and sequence): How are parts of the unit combined? Outline the content--lay out the scope and sequence of content for the entire unit. This should be a descriptive outline from introduction to the end of the unit. (2-3 pages of outline)

Planning grid (scope and sequence): A planning grid is absolutely necessary and acts as a flowchart that provides the details for putting the unit in action. In the order in which they will be introduced, briefly annotate (describe) the lessons, activities and means of assessment, and list the objectives and materials reference. This will reflect the content, lessons and activities to be selected, and the week-by-week sequence-order of curriculum. (5-6 pages of grids)

Activities, modules, & projects: Include Activity, Module, and Project Descriptions. This will reflect the depth of the content that you select. Consider alternative and holistic modes of student expression and ways of knowing. This should include handouts for the students. (6-10 pages of activity, module & project descriptions)

Procedure, safety, and information sheets: Include standard handouts for teaching in labs and workshops. Prepare at least two groups (Procedure + Safety + Information) for specific activities related to an apparatus, tool, material, machine, or process for the projects in the unit. This should include handouts for the students and templates for overheads. (6-12 pages of procedure, safety & information sheets)

Assessment: Include criteria, rubrics, and schemes for the assessment of individual activities. Provide details for quizzes, observations, portfolios, and project assessments with which students will be assessed. Indicate how results of assessments will be communicated. Include handouts for students.

Lesson plans: Include lessons plans for all of the formal lessons that the teacher will deliver. (Number of pages will vary, depending on number of lessons)

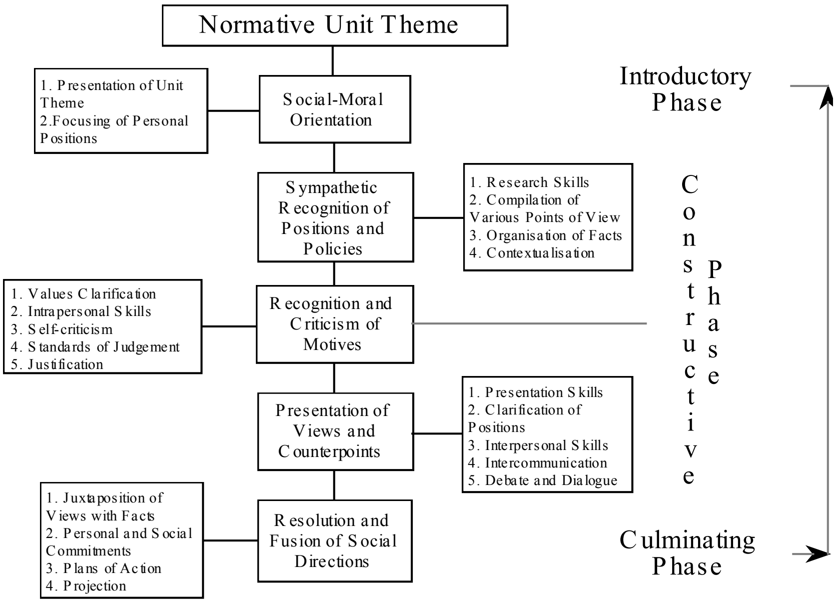
Semantic or concept maps: Include mind maps that elaborate on specific ideas and content within the unit. (3-4 Maps)

Resources: Indicate resources that are necessary for you and your students to enrich the unit. Assume a standard lab or shop environment with average tools, materials, and equipment. List books, Web sites, special software or technology, etc. (List with bibliography- 1-3 pages)

Table 4. Example planning grid

Grade 11	CAD		10 Hrs (Week 1-2)	
Topic and Time	**Objectives and Outcomes**	Activity	Assessment	Resources
Intro to CAD (1 Hour)	Students will: appreciate the precision and uses of CAD. Describe a CAD system.	Sample drawing manipulation	Observations	PowerPoint Intro
CAD file manipulation (1 Hour)	Open, close and save files	Simple CAD drawing exercise	Observations	CAD file handout
Etc.				

Figure 7. Normative Unit



from a general form of progressing from an introductory phase through constructive and culminating phases. However, a normative unit focuses on the resolution of a controversial issue. The form of a normative unit is as follows:

1. Social and moral orientation of students
2. Sympathetic recognition of opposing positions, practices, and policies, or fact finding

3. Conscious recognition and criticism of personal motives, aspirations, beliefs, and outlooks
4. Presentation of personal and social views
5. Resolution or fusion of social directions and standards of judgment with facts and descriptive principles into programs and plans of action

The very form of the unit is designed to discourage fence sitting. Neutrality and apathy on the part of the students are signs that the their core beliefs and feelings have not been touched by the unit. Normative units hold a possibility for providing insight into controversial issues such as those listed in Chapter IV (Figure 7).

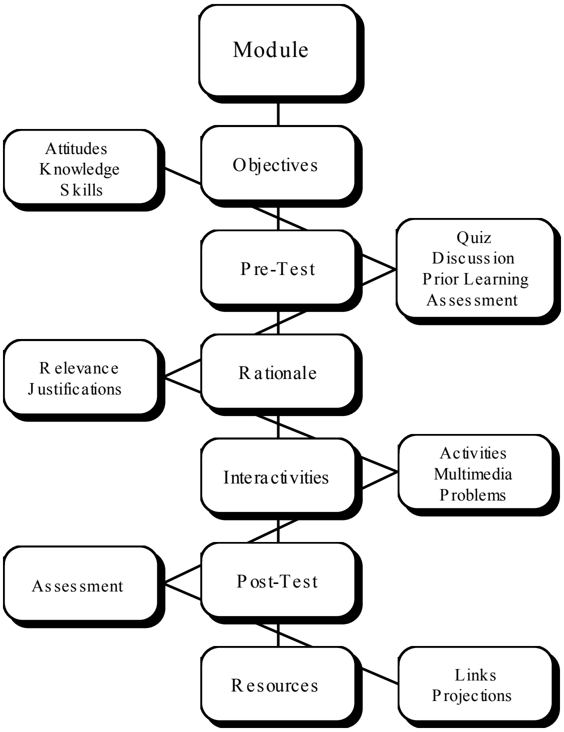
Modules

In the early 1970s, an individualized learning package or container for modular teaching was called a module—"a self-contained, independent unit of a planned series of learning activities designed to help the student accomplish certain well-defined objectives." Modules are free-standing, self-contained, and comprehensive instructional packages, meaning that basically everything that the student needs is in the module (Petrina, 2004). Whereas a unit is directed by the teacher and may involve the use of modules, a module provides for self-direction, or self-paced learning of a realm of content. In the late 1980s and through the 1990s, modules became immensely popular in England and Scotland in a context of "flexible learning," educators' response to flexible economics. The basic form of modules was established by instructional designers in the 1970s (Figure 8).

Modules are immensely popular and extremely important for anyone interested in the development of digital learning resources and on-line education. Most schools are moving toward mixed modes of teaching, which invariably involves the use of digital modules. Modules need not be digital, but a vast majority are taking a digital form in this context. In the next section, the details of a digital module format are provided.

In technology studies, the popularity of modular instruction increased throughout the 1990s. In 2001 in the U.S., 72.5% of technology education programs in public schools were using teacher-made modules and 48.5% use commercially vendored modules (Brusic & LaPorte, 2000; Sanders, 2001). During the 1990s, the commercial production of modules became an attractive endeavor for vendors who marketed their modules at prices ranging from $8.00 for a paper packet to $12,980.00 for integrated learning systems (Petrina, 1993). It is important to stress that there are two connotations of modules: (1) The self-contained instructional packages (often

Figure 8. Module



digital) already described; and (2) Self-contained instructional packages integrated within a structural, workstation environment. This second type refers to modular "stations" that are basically self-contained mini-facilities. We can think of the first type as software modules and the second type as a integrated workstations of software, hardware, and architecture (see Chapter XI). Hence, modules range from do-it-yourself packages to desk-top trainers to architectural spaces defined by specialized equipment.

Delivery Systems

One proponent of online learning referred to the proliferation of software modules as "The Container Revolution," reflected in the 700+ modules at Oxford Polytechnic (Watson, 1989, pp. xvii, 1). Modules are currently a world-wide phenomenon and preferred "containers" within e-learning delivery systems (Bourdeau & Bates, 1997; Hashim, 1999). Popular courseware, such as WebCT, Blackboard, and Moodle, are designed to make modules accessible to students and provide a rich digital environment for interaction. Critics note that courseware necessarily automates C&I and introduces into teachings all of the problems associated with industrial automation, including a displacement of labor (Noble, 20002; Petrina, in press). However much the concept of "delivery system" suggests automation, there is a range of options for teachers.

ID specialists note that there are four general delivery system options: face-to-face (F2F), online, distance correspondence, and blended or hybrid. During the first three decades of the 20th century, the rise of correspondence education raised the question of delivery system, an irrelevant question in previous eras of F2F classrooms. Radio and television added an electronic dimension to the question of delivery, and as indicated in the previous section, the 1960s and 1970s ushered in modularity as a form of delivery (Petrina, 2003). Now, teachers are faced with a range of options, primarily provided by the accessibility of ICT for C&I. A concern that engineering, design and technology teachers once had—can skills be taught via distance or online education?—is now irrelevant (Zirkle, 2003, 2004). For decades, students honed bread-boarding and electronics design via distance education and training kits and circuits mailed back and forth to instructors. Indicative of Web-based delivery, the National Engineering Education Delivery System (NEEDS) was designed to encourage engineers to adopt mediated approaches to learning via online delivery systems (Muamatsu & Agogino, 1999).

Excluding distance courses, technology teachers find that blended course systems work best. Most technology teachers, especially in high schools, use a blend of F2F and online delivery systems. Commonly, technology students interact within F2F environments in labs, studios, or workshops, and transition across workstations to complete digital modules challenging them to resolve design solutions and develop their projects. Teachers in these courses draw on delivery systems that range from conventional F2F demonstrations to DVD media and online, digital modules.

Course Design: Putting it All Together

The scale of C&I increases as teachers move from lessons and activities to problems, modules, projects, units and courses. Successful technology teachers are fully competent with both curriculum and instructional design along these various scales, from lessons to courses. Regardless of delivery system, a course is a synthesis of these various scales (Posner & Rudnitsky, 1994). Courses and credits are conventional components for configuring credentials and transitions from grade-to-grade, school-to-work and secondary to post-secondary levels. Some institutions have tried to provide flexibility by standardizing modules that students can complete in customized ways to eventually accumulate course credits.

Course design assumes a designer who is competent in lesson and activity planning, problem, module, project and unit design, assessment, and content and goal discretion or selection. These competencies assume a familiarity with the larger program or school curriculum as well as the state-of-the-art of the specialized profession. All of this assumes competencies in C&I theory. Will you design transmissive or transactive curriculum? Or will you design more transformative courses for your students? How will you address equity in your curriculum materials and courses? Will you adopt a principle of equal access or will you make more systemic changes to empower boys and girls with anti-oppressive perspectives? Although certain aspects of courses are emergent or cannot be anticipated, teachers who plan out course details minimize classroom incivilities (Chapter XI) and have consistent successes with C&I. On one hand, well-designed courses facilitate success. On the other hand, a well-designed course, articulated within a fairly detailed course outline, is a preventive measure for anticipating problems that may occur. Example 1 provides an example of elements and sections common to a high school course outline (or syllabus).

Example 1.

West Side High School

Technology Studies Department

Course Outline: CAD and Engineering Graphics

Teachers: Ms. Watters and Mr. West

Room: CAD Lab

Web Site: http:://www.westsidehigh.pittsburghdistrict.edu/technology/CAD

Course description: This is an advanced course for any student interested in engineering and digital graphics. You will learn how to use CAD to create and present technical information and engineering designs. This course will prepare you for careers and further studies in technology. We will combine theory with hands-on activities, modules, projects, and units.

Books: We will use the West Side High CAD and Engineering Graphics Course Packet and Discovering AutoCAD by Dix & Riley. No books can be taken out of the lab. There are copies in the library to borrow. Ask you teacher for more information on this policy.

Software: We will use AutoCAD Lite, QCAD, and Blender.

Goals and objectives for the course: Upon completing introductory design drawing courses, the student should be able to:

1. Express basic ethical and cultural issues of CAD and engineering graphics.
2. Create graphic representations of problems commonly found in design with CAD.
3. Accurately describe and communicate the relative size and shape of surfaces as well as solids through multiview and pictorial representation.

4. Mentally visualize the shape of 3D objects through graphical techniques.
5. Apply commonly accepted, conventional practices and standards to graphic solutions to problems.
6. Describe the basic computer graphics concepts underlying the software tools used in CAD.
7. Understand the basics of using CAD representations of designs in processes common to the design profession.
8. Integrate basic design graphics, concepts, and skills to a project relevant to the field of design.

Course policies:

- You are required to be in the lab when class starts.
- No Food or drinks in the lab!
- Please do not try to fix any hardware problems. Ask your teacher for help.
- The only games you are permitted to play in the lab are games that you are designing components or images for!

Assessment:

1. Module #1- 5 marks
2. Module #2- 5 marks
3. Module #3- 5 marks
4. Quiz #1- 10 marks
5. Quiz #2- 10 marks
6. Five Projects- 6 marks each
7. Portfolio- 35 marks

*Total= 100 marks

* Each assignment will be assessed with the rubrics included in the West Side High CAD and Engineering Graphics Course Packet.

Content outline: See the course content section of the West Side High CAD and Engineering Graphics Course Packet.

Copyright for C&I and Academic Freedom

Invariably, technology teachers face questions of copyright in designing C&I. One question concerns the "fair use" of images, text and sounds in teaching and research. A second question concerns the rights to or ownership of C&I products created by a teacher. What C&I materials can I use in my classroom within the terms of copyright law? Who owns the C&I materials I create? This is an especially exciting time for copyright because of additional questions that digital property raises. Can I freely download images, text, and sounds for use in my classroom? Intellectual property rights (IPRs) in general, and copyright specifically, are among the most contentious issues in cyberspace. Copyright law has attempted to accommodate cyberspace by merely calling it a conveyance--another shell or format--for the content of expression. But critics, such as the Electronic Frontier Foundation, argue that digital property cannot be contained the way that physical property can. Hence, the argument for Creative Commons licensing and open source file sharing approaches to digital files.

To facilitate curriculum design, teaching and academic criticism, as well as free expression, the U.S. and Canada copyright acts contain clauses for "fair use" (U.S. Copyright Act, 2005, Section 107) or "fair dealing" (Canada Copyright Act, 1997, Part III). The U.S. Copyright Act (1994) states, with limitations, that a copyrighted work used "for purposes such as criticism, comment, news reporting, teaching (including multiple copies for classroom use), scholarship, or research, is not an infringement of copyright" (Section 107) (see also U.S. Copyright Office, 1998). Limitations are placed on the type and volume of materials used from single sources, and the frequency of use of the materials. Canada's Copyright Act provides a clause for instruction, but places stricter conditions on photocopying copyrighted material as handouts for students. In Canada, teachers can legally make multiple copies of copyrighted materials by working within the parameters established by Access Copyright, a copyright collective that manages royalties for authors and publishers. Fair use and fair dealing require that the source of materials be noted, works are attributed to authors, and integrity of the works are preserved (Noel, 2005). Teachers can freely use works that are in the public domain, wherein copyright has expired or made accessible through an author's intentional assignment to the public domain and licensing schemes such as the Creative Commons and copyleft.

Ownership and oversight over the C&I materials you create are different matters. In Canada and the U.S., copyright is automatically granted to authors but this is governed by institutional contexts. In most cases, the employer is assigned the copyright for products created in the normal scope of employment. However, by tradition in copyright law, teachers have an "academic exception" or "teacher exception" to the practice of assigning copyright to the employer. As a result, teachers have copyright in their "work product" unless otherwise specified in writing, where work is done under conditions of "works made for hire" (U.S.) or "work made in the course of employment" (Canada). The academic exception has withstood challenges in the courts, but is also under threat in an era of online education (Holmes & Levin, 2000). Teachers ought to be cognizant of the copyright policies within their schools and districts.

Copyright ownership of curriculum materials implies oversight and professional judgment over what teachers can teach and do with the materials they create. Teachers have been notoriously generous with C&I materials they create and opencourseware or open knowledge initiatives encourage teachers to share their course materials online using Creative Commons arrangements. Oversight over the curriculum of the schools is a joint effort among teachers, administrators, district and government officials. Oversight raises a question of academic freedom, or freedom to teach without interference or censorship. Recall that it was once illegal for teachers to use C&I materials that explained evolution. In the 1940s and 1950s, materials with a critical perspective on technology, such as Marx's *Capital*, were often banned. Currently, materials with gay and lesbian content, and books such as Adventures of Huckleberry Finn, are often banned from use in schools. This is one way in which the taught or official curriculum is regulated (Apple, 2003; Ayers, 2004; Daly, Schall & Skeele, 2001; Strope, 1999). Technology raises questions of copyright, but the subject also raises questions of academic freedom and what teachers can teach about the subject that is excluded from the official curriculum.

Projection and Reflective Practice

We began this chapter by asking "who should design the curriculum that technology teachers teach?" We acknowledged that technology studies traditionally drew on the curriculum and design skills of the teacher. This had its advantages. However, this was a disadvantage in terms of consistency in curriculum, as was noted in the Chapter VIII. During the 1990s, a fair amount of curriculum design in technology studies was vendor driven and commercially produced. The Web also added a new dimension of portability of curriculum materials for teachers who are part of the learning objects movement. While more curriculum is commercially and publicly available and convenient than ever before, technology teachers must continue to possess the ability to design an effective materials, projects, units or modules. The principles of ID and formats provided are essential tools for each technology teacher. In the next chapter, the topics of assessment and evaluation are addressed.

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Section III

Implementing and Evaluating Curriculum and Instruction

Chapter X

Assessment and Evaluation

Introduction

Some teachers view assessment as a necessary evil. Some view assessment as their only real tool of discipline and power. Still other teachers view assessment as an integral part of C&I, and the pivotal practice around which teaching methods and communication turns. Most teachers appreciate local, teacher-controlled assessment and loathe the high stakes assessment that produces anxiety, fear, and competitive tactics. For many administrators, parents and politicians, assessment has its justifications in accountability to standards. Indeed, it is difficult to navigate through the various forms of assessment and perspectives on assessment that teachers face on a daily basis. Everyday assessment entails hundreds of observations that teachers make of their students. This involves informal discussions, feedback and deliberate, staged activities and performances. Assessment involves volumes of documentary evidence, from daily assignments, quizzes, and tests to observations, projects, and digital artifacts. In its most stereotypical form, assessment in technology studies simply meant putting a mark on a completed project, much like a merchant places a price on a product. By current standards, this was inauthentic assessment. Since the late 1980s and early 1990s, authentic assessment has transformed the way we think about and carry out assessments in the schools. Technologies of assessment had similar effects.

Evaluation, which typically pertains to facility, program, or teacher evaluation, has conflicts and interpretations that are similar to those of assessment. With both assessment and evaluation, the goals are to provide feedback, to rank or sort and to provide a means of communication. However, in many cases there is a lot at stake for those who are being assessed and evaluated. It is no secret that, in light of these stakes, students can resort to desperate means to beat the assessment system. On the Web, an entire market for cheating has been generated in response to demands for devices to beat the system. The purpose of this chapter is to provide an overview of assessment and evaluation. We will focus on the types of assessments and evaluations that are complementary to practice in technology studies. We will also raise fundamental questions regarding the relevance of high stakes tests of technological literacy.

Assessment in Technology Studies

Currently, I administer a *Scale of Design Capability* each year to my new groups of students. This scale tells me, with some degree of accuracy, the varied levels of the students and exactly who will succeed as a design and technology teacher. The scale is tuned to a simple, particular performance. I have the entire group remove their shoes and, with my scale safely secured on my clipboard, monitor each student's

Table 1. Scale of design capability

Sorting process	**Student**	**Possible**
All shoes sorted		5
Small sizes sorted first		5
Boots sorted first		5
Trainers sorted second		5
Other shoe types sorted last		5
Shoes sorted within 6 minute limit		5
Sorting outcome	**Student**	**Possible**
Size presented from small to large		5
Shoes presented by colors (blues with blues, reds with reds, etc.)		5

Table 1. Scale of design capability

Shoes facing in same direction (toes in 1 dir.)	5	
Shoes placed accurately in four rows and three columns	5	
Shoe pairs placed 25-30mm from each other	5	
Shoes cleaned and dried	5	
Design capability =		**/ 60**
Attitude		
Shoes sorted with positive attitude		/ 5
Total		**/ 65**

design capability. Each student is given one trial to sort the shoes and I assess accordingly. Here is the scale that I have refined over the years:

After administering the scale, I tally up my marks and rank the students. I convert the marks to percentages. It is a good measuring scale because only about one-quarter of the students score higher than the mean, which is typically around 75%. Design is something that not everyone is good at and this scale basically proves it. I do *not* give them the scale prior to their performance, as this would remove the element of true design capability. Their identification with the criteria would spoil the performance and eliminate spontaneity. The entire process of assessment provides me with a pretty good judgment about who can design and who is weak. Of course there is always room for the students to improve. I have come a long way, as I am now rating process as well as product. The scale quantifies both process and product. I really like administering this scale because it allows me to model the way we want to assess students in the schools!

Pause: *Is there anything wrong with this scenario? Is the Scale of Design Capability valid? How authentic is this process of assessment?*

When I taught drafting and CAD, I merely assessed the students' drawings and plotted files. I had objective criteria that I used for each drawing, but the result was that

I was grading products and not students. I often got caught up in the assessment of artifacts rather than students. As mentioned in Chapter II, I wrote NEATNESS--2 across messy drawings to indicate my assessment of how the drawings looked. I deducted marks for ACCURACY as I assessed the solutions and for STANDARDIZATION as I assessed adherence to conventions.

Pause: *Is there anything wrong with this scenario? Was my assessment of drawings and files valid? How authentic is this process of assessment?*

For the CAD courses, I created a final exam that was comprehensive. It addressed all of the content covered in the course and I sampled from each unit and topic on the content outline. The exam consisted of 100 problems (true-false, multiple choice and matching) and was quite challenging for the students. The exam sorted the students fairly well but not quite according to a normal distribution (i.e., Bell Curve). The exam did not involve any problems that required the students to use CAD. The exam was worth 20% of the final grade. Drawing and modeling assignments were used for 65% of the final grade. A heavy emphasis was already placed on drawing and modeling so there was no need to require more of this in the exam. After all, there was more to the course than drawing and modeling.

Pause again: *Is there anything wrong with this scenario? Was my exam valid? How authentic is this process of assessment?*

Projects

Projects typically culminate in an artifact, medium, or performance that relates to the original purpose. As explained in the previous chapter, projects are not things, but may culminate in things. Projects or other forms of evidence for grading are not merely produced for the purpose of assessment. Projects and their artifacts ought to be produced in response to the larger aims, ends, or objectives of the course or program. As indicated in the last chapter, projects should not be seen as ends in themselves. Rather, the intended artifacts of C&I ought to disclose conditions of modern life. All too often, as Custer (1996) observed, teachers get caught in one of two traps. The first is the “Project Trap,” in which the artifacts of the project are selected as ends in themselves and the only good reason for their adoption. Here, the cart is placed before the horse (i.e., the course exists so the students can create this or that artifact). The second is the “Neat Activity Trap.” Here, teachers select projects because they are entertaining, rather than by identifying what specific content, emotions, and skills will be reinforced. Teachers often end up adapting their course to fit activities rather than adopting activities to fit the course.

Artifacts and media range from digital images and text to three-dimensional models, drawings, paintings, sculptures, songs, and useable products. As indicated in the previous chapter, some technology teachers argue that students must take a tangible artifact home. Teachers who tend to over-emphasize projects typically assess products for quality, to the neglect of processes—they assess projects rather than students. The product overshadows the value of the process. After the completion, the product is assessed for quality. In the woodworking courses of industrial education, a clock or table was assessed and given a mark of quality. Thirty products for thirty students were often lined up and given a mark. In information technology, spreadsheets were created and assessed. Of course, this still takes place and we are all guilty of this practice. But this kind of practice is not unique to technology studies. Math and science teachers assess problems; art teachers assess paintings. However, the trend in all subjects is to refocus on the process rather than the product.

In subjects such as art, business, home economics and technology where projects have dominated the school curriculum for well over a century, the transition from assessing projects to assessing processes is a special challenge. Learning about design and technology requires thatproducts be submitted to public critiques. Critiques or judgments of artifacts are a central facet of the design process (see, Figure 6). Critiques of the products of technology are also necessary modes of public feedback for engineers, designers and other technologists. Artifacts, including artistic artifacts, must never be above judgment. Designers and technologists tend to be quite pragmatic, assuming that solutions and "what works" are of interest and the process is secondary. Artists tend to look for aesthetic qualities in products. Some teachers react to the general decline of quality in technological practices and products and take a hard stand with the quality of their students' projects. So there are some very good reasons to assess the quality of projects.

In addition, the trend toward the assessment of processes is accompanied by a trend toward outcomes-based education (OBE) and norm-referenced assessment. OBE was manifested in the increases of standardized tests and standards throughout the 1990s. "Outcomes," for most administrators, parents and politicians, mean scores on standardized tests. These types of high-stakes assessments are norm referenced—comparisons are made with national and international averages and norms. In effect, technology educators, like art educators, find themselves reacting to two contradictory forces or trends. One trend is toward the assessment of processes and the other is toward the assessment of outcomes *via* standardized tests. As indicated in Chapter VIII, the content of technology studies is the primary justification for the subject. Hence, we cannot dismiss standardized tests of content. We have to respond to both forces at the same time.

In Chapter VIII, the arguments for a process-based curriculum were explained. The example of CAD was used, where instead of concentrating on the commands of AutoCAD and associated skills, teachers began to shift their efforts to the processes of communication, visualization, representation, detailing, documentation, presentation, and modeling. In general, process-based curriculum includes a shift toward intellectual processes such as observing, analyzing, computing, measuring, predicting, experimenting, modeling, creating and communicating. The challenge is *how* to assess the students. Projects provide *one* rather convenient form of *evidence* of these processes. Projects can be a powerful instrument of authentic assessment *if* we assess more than merely the artifacts. The project is *not* the artifact.

Authentic Assessment

A fair program of assessment demands a range of forms of documentation and evidence, such as experiments, images, innovations, interviews, quizzes, observations, presentations, problems, projects, portfolios, recordings, and rubrics. A fair program demands that we assess authentically. The techniques of authentic assessment help provide for a fair assessment of both products and processes. At this point, and to address these issues, it important that we have some working definitions of assessment.

- **Assessment:** Monitoring, documenting and communicating levels of quality and quantity of performance. Assessment is done in order to: (1) provide feedback for learning & growth; (2) rank or sort according to some characteristic; and (3) provide means of communication with parents, administrators, teachers, etc.
- **Formative assessment:** Assessment that is progressive in that the students'' progress is monitored and communicated at different periods in time throughout the course, unit, term, etc. "In-progress" assessment.
- **Summative assessment:** Assessment is final in that the students' performance is assessed at the end of a unit or course. "Final" assessment.
- **Authentic assessment:** Assess the genuine, "real," or actual thing (person, performance, etc.); Assess fairly; Use assessment to enhance learning.

Authentic assessment means that we assess the genuine, "real" or actual thing (person, performance, etc.). It means that we assess fairly and use assessment to enhance learning. Authentic assessment is that which has meaning in itself, has value beyond the classroom and is meaningful to the students. Assessment that directs and redirects learning is by necessity flexible and deals with a wide array of what students know, feel, and can do. Where quizzes and exams traditionally test for low-level cognitive processes (e.g., recall, recognition) and are primarily summative assessments, authentic assessments allow us to assess a wide expression of dispositions, knowledge, and skills and is primarily formative assessment. Assessment should be flexible enough to accommodate various learning styles and multiple intelligences. Authentic assessment has the potential to be an equitable and fair way of assessing and judging experience and expressions of competence.

Technology studies, with its experience-based nature and project or problem-based orientation, is well attuned to authentic assessments. Yet, as indicated in the section on projects, technology teachers have been slow to shift their assessments toward authentic techniques. Project assessment is not *ipso facto* authentic assessment. The range of activities in technology studies nevertheless lends itself well to authentic techniques. The most effective techniques include portfolios, performances and criterion-referenced assessment (rubrics) (BC MoE, 1994a).

Table 2. Techniques of authentic assessment

Portfolio assessment: Assess results and evidence of results over time.

A good portfolio...

- Has a clear purpose that was communicated clearly to all involved.
- Organizes level-appropriate activities that students are familiar with.
- Organizes evidence of process (as opposed to merely collecting products).
- Requires students to describe contents.
- Provides ample space to store contents.

Performance assessment: Assess the performance.

A good performance is...

- Congruent with the purposes of assessment.
- Interesting, challenging and fair for all students.
- Authentic; promotes transfer to other performances.
- Reflects intended outcomes and goals.
- Appropriate for the students' level of development.
- Directed by clear expectations of what is to be done and under what conditions.
- Directed by adequate information for successful completion.

Criterion-referenced assessment (Rubrics): Assess according to predetermined and communicated criteria.

A good criterion or rubric...

- Communicates essential standards of achievement.
- Operationalizes outcomes.
- Applies across contexts for similar behaviors.
- Focuses on current instruction, not prior learning.
- Is essential to judge the performance adequately.
- Communicates to all (students, teachers, parents) what is critical to successful levels of performance.

Table 3. Characteristics of authentic assessment (Kerka, 1995)

- Engaging, meaningful, worthy problems or tasks that match the content and outcomes of C&I.
- Real-life applicability.
- Multistaged demonstrations of knowing, knowing why and knowing how.
- Emphasis on process and product, conveying that both development and achievement matter.
- Rich, multidimensional, varied formats, both on-demand (in-class projects), and cumulative (portfolios).
- Opportunities for learner self-evaluation.
- Cognitive complexity requiring higher order thinking skills.
- Clear, concise, and openly communicated standards.
- Fairness in rating and scoring procedures and their application.

There are eight general questions that ought to guide assessment and help teachers link assessment with C&I: What should learners know and be able to do? What emotional, cognitive, and sensorimotor skills should they demonstrate? What types of activities, problems, or tasks involve those skills? What concepts or principles should be applied in performing those tasks? What are the reasons for this assessment? What use will be made of the results? By whom? What criteria should be used? The key to planning for authentic assessment is to plan for curriculum, instruction and assessment at the same time. The single most significant characteristic of assessing authentically is that assessment matches C&I.

If teachers use techniques of authentic assessment and use quizzes or tests that are fairly objective, the actual grading or marking of individual items should not be an issue. Nevertheless, anytime a teacher assigns a numerical or letter grade to a performance, s/he must be accurate, careful, consistent, and honest and systematic. Teachers must keep their biases in check as much as is humanly possible. Techniques of authentic assessment are of great assistance for this.

Portfolio Assessment

A portfolio is a *collection* of documents that attest to performances and proficiencies. A portfolio is an *attestation* of work—entries in the portfolio should have a brief description of what the selections attest to. The selections or entries should attest to particular aptitudes, knowledge, proficiencies or values. A portfolio provides evidence of dispositions, knowledge, and skills; it is a *collection* of evidence. This evidence represents a selection (typically the student's selection) of ideas and work, from various points and courses in time, regarding a student's performance and proficiency. Technology portfolios are typically ongoing projects, providing evidence of the students' progress in technology studies. Portfolios keep open the question of expression and may include combinations of artifacts, attestations, and productions (notes, drafts, journal entries, sketches, lesson plans, letters, drawings, programs, photographs, videos, audios, models, etc.). Portfolio assessment emphasizes the importance of student responsibility in their education by including them in the assessment process and by involving them in goal setting and criteria.

Portfolios serve as a catalyst for reflection on growth and development—students will have an organized collection of their work to review and think about as they transition from level to level. Portfolios also serve as a record for presenting oneself to potential employers or institutions of advanced education. With their various uses beyond the classroom, they are one of the most important means of authentic assessment.

Because of the varied artifacts created in subjects such as art, design, and technology, there is a tradition of portfolio use. But this tradition is limited to professional schools and practices. Professional animators, architects, artists, designers, and engineers are dependent on their portfolios to get them contracts, jobs, and advancements. Many maintain their portfolios over an entire career of 30-35 years of practice! Yet, for the most part, technology teachers were reluctant to use portfolios as a means of student assessment until the 1990s. This decade marked philosophical changes in the transitions from industrial to technology education and educational to information technology. Now, it is quite common to find the use of portfolios in labs and workshops. Digital technologies provided a catalyst for the adoption of e-portfolios in technology studies. In fact, entire districts and educational systems have turned toward e-portfolios. It is relatively easy to digitize 3D artifacts and place an entire e-portfolio online. Mark Sanders (2000) at Virginia Polytechnic and State University, began to place his students' e-portfolios online in the mid 1990s. Numerous e-portfolio applications, from proprietary to open source, are now readily accessible and convenient. However, most technology teachers find that constraints of e-portfolio applications standardize and limit design options for students. An e-portfolio is not a distinct type of portfolio, rather it is a mode of presentation.

There are three types of portfolios: Working Portfolio, Presentation Portfolio, and Cumulative Portfolio (Table 4). A working portfolio is "an ongoing collection of self-selected samples of work that are used to highlight the students' efforts, progress, achievement, and reflections." A presentation portfolio includes samples selected by the student and teacher. These samples are then *presented* to the teacher, potential employers or advanced educational institutions. A cumulative portfolio includes selections from working and presentation portfolios over long periods of time (i.e., years) (BC MOE, 1994b, p. 4-5).

Table 4. Types of portfolios (Adapted from BC MOE, 1994b)

Portfolio	Purpose	Content	Audience
Working	· To help students assess their work. · To help students observe patterns in their progress.	· Many samples of student work from many or one subject.	· Student and teacher.
Presentation	· To assist students in communication about their work and progress.	· Selected samples that represent a few chosen aspects of student work.	· Teachers. · Parents. · Future employers. · Advanced educational institutions.
Cumulative	· To help educators know where their students are in their education. · To assist in planning student programs. · To help students prepare for the real world.	· Selected samples of student work. · Student progress reports.	· Students. · Future teachers. · Administrators. · Future employers. · Advanced educational institutions.

Working portfolios help *describe* what students are doing and what they can do. The variety of samples included provides an indication of competencies. Presentation portfolios *showcase* the students' work. A select few samples are provided to highlight the best of what a student can do. Cumulative portfolios are *evaluative* in that they allow for a longitudinal judgment on the students' progress (Hoepfl, 1993).

My experience with digital portfolios suggests that it is best to provide a checklist of the artifacts students are expected to provide in their portfolio. They can select the artifacts for the various categories.

Performance Assessment

Performance assessment was a response to the limitations of standardized, norm-referenced testing. Performance assessment means that students demonstrate what they can do—we assess the actual performance of challenges and tasks. For example, if the students are expected to solve problems, then we must assess the way they perform in the process of problem-solving. We cannot merely assess the products of the problems they solve. The assessment of performance can be informal (observations of everyday progress) or formal (recording a structured event or situation) (BC MOE, 1994a).

Performance assessment derives from the world of work. If a manager wants to assess an employee, rarely will they give a job-specific test. They observe the employee's performance on the job—at the job site. However, managers are much less interested in authentic assessment than teachers. Hence, they often rely on secret assessments and assessors such as "mystery shoppers" hired to rate the performance of sales clerks or associates, and phone or computer monitoring software to monitor and assess receptionists. Authentic assessment requires that the students be informed when their performances are being assessed and the criteria used for assessment. Teachers are challenged to assess students "in the task" and communicate the means of assessment. Performances in technology include the creation of digital media, experiments, models, open-ended design and engineering problems, prototypes, research projects, technology fair projects, and an assessment of a new technology.

There are a few issues that teachers must be cognizant of when they use performance assessment techniques. Performances raise the question of developmental sensitivity, as younger students will often simply mimic adult capabilities and roles. There is also the problem of merely teaching students to perform, requiring cosmetic expertise at the expense of other important goals. Assessments structured around tasks, instead of constructs (such as student comprehension), risk a returning to simple behavioral assessments. Quite often, unintended consequences stemming from the specific tasks will unfold. For example, students mocking a required task may in fact be demonstrating a deep understanding of the task and in effect the irrelevance of it their lives. These unintended consequences need to be documented as they arise from the approach to assessment. Teachers using both outcomes-based testing and performance assessments are often left to deal with potentially conflicting teaching methods and educational goals. Their students are left to resolve the conflicts on their own. In summary, performance assessment requires careful attention to the setting, specification of criteria, multiple samples of student performance, and attention toward evidence and validity.

To be effective, performance assessment must be criterion-referenced assessment. This means that student performances are judged against pre-set criteria and performance standards rather than against each other. Performance assessment is impossible without clear criteria established well before the process begins. This is one of the most difficult challenges for teachers.

Criterion-Referenced Assessment and Rubrics

Assessment criteria are characteristics or guidelines with which we judge the performance of students. Assessment criteria are created and given to students prior to the event, situation, problem or project that will be assessed. Criterion-referenced assessment is based on the criteria created for different levels of performance (e.g., excellent, good, satisfactory, minimal, poor). The performance of students is compared to the criteria of different levels to provide feedback to their performance and determine their standings for reporting marks. In norm-referenced assessment, students are compared to the norm or group. In criterion-referenced assessment, students are compared with criteria rather than each other.

Some of the earliest forms of criterion-referenced assessment were established in England during the mid 1970s for the craft, design, and technology projects. The criteria represented an attempt to make the assessing of projects consistent and objective. Although not named as such, these were early attempts to make assessment authentic. One rather comprehensive approach took the form of a matrix or what we refer to as a rubric (Starmer, 1974). Criteria are developed for each concept at each level, titled Conception, Designing, Production, Valuation, Personal Qualities. The criteria for designing are provided in Table 5. The key concepts are listed in the left column of the rubric and levels of performance, or marks/points, along the top row. These criteria were given to the students prior to their performance and altered a bit to meet particular problems and projects.

From this tradition of rubrics for judging design and technological action, cognition and emotion, British technology educators have been quite progressive in their as-

Table 5. Expansion of design criteria in CDT Rubric (Adapted from Starmer, 1974)

	1	2	3	4	5
Designing · Formulation of design.	The project commenced with minimal thought of the progression of work	One solution considered but sketchily prepared	Only one solution but a good design of this prepared	A design prepared after alternative approaches have been mooted	A design formulated after careful consideration of several different approaches
· Testing of workability.	Only superficial testing	Reluctant to check any aspects	Tested and checked some aspects	Tested and checked major aspects where practically possible	Tested and checked all aspects where practically possible
· Suitability of design.	Specification badly adhered to	Specification adhered to only in a few aspects	Design fulfills specification in almost all aspects	Design fulfills specification but is too complex or not comprehensive enough	Design fulfills specification simply and comprehensively within limits of design brief

sessment techniques. Researchers adapted these original rubrics, entered the labs and workshops, and rated or scored the practice of the D&T students. National assessments were made in the late 1980s by researchers such as Richard Kimbell (1997) at Goldsmiths College in London. While rubrics were constructed in Canada and the U.S. during the mid 1980s, North Americans have been slower to accommodate criterion-referenced techniques.

Criterion-referenced assessment is nevertheless catching on with the growing popularity and utility of rubrics. Rubrics are the primary means for implementing criterion-referenced assessment. They are scoring or rating devices "designed to assist in the process of clarifying, communicating, and assessing expectations. Rubrics are grading tools which contain specific information about what is expected of students based on selected or defined criteria" (Custer, 1996, p. 29). One innovative aspect of rubrics is in the detailing of criteria or performance standards across multiple levels. Scales that merely left a number or letter to circle were transformed into much more detailed scales that communicate explicit criteria across multiple levels to students. In an earlier section, we inquired about the assessment of projects. We noted that technology teachers were in a (bad) habit of assessing projects by judiciously focusing on the artifact—on the tangible product of the project. They might have measured the artifact to determine how closely the finished sizes adhered to the blueprint dimensions in a production course. They might have measured the registration of screen prints superimposed on one another in a graphics course. They might have measured margins and the alignment of images and text in an information technology course. We noted that a formal assessment of the process was rarely made. A second innovative aspect of rubrics is the focus on process. Rubrics help us to focus on the process in an open manner—we create rubrics to give to students prior to our assessment. We create rubrics for assessing both processes and products. They help remove some of the subjectivity often associated with the assessment of processes. Generic and template rubrics help eliminate the need for constant adaptation to particular activities and projects. For example, David Romani (2002), a teacher in Vancouver uses a "generic" employability skills rubric as a complement to the assessment of activities and projects that the students complete in his secondary school (Figure 4).

The actual rubric has five levels of performance. Specific rubrics are created for the individual artifacts he assesses. Custer (1996) highlighted a generic rubric used by Jeanne Kirchoff (1996) in her school in Troy, Missouri (Figure 5). This rubric is used to assess the type of small group work and teamwork demanded by group design briefs and projects.

These rubrics can be customized and tailored for local courses and schools. A team of BC technology educators developed the following rubric for Web design in 1996 (Table 8) (BC MOE, 1996).

When general rubrics for employability and social skills are combined with rubrics for specific technology tasks, we have a powerful set of assessment tools. The

Table 6. Employability skills Rubric (Adapted from Romani, 2002)

Criteria	Level 1(A)	Level 2(B)	Level 3(C)
Communication	Successfully conveys and retrieves information in written, oral and sketch format.	Clearly articulates & supports information in two of the three formats	Evaluates the importance/relevance of each format and its sources.
Autonomous learning	Models relevant techniques to assist the brain in acquiring new information	Successfully demonstrates the patience and perseverance needed to accept new information that is ongoing.	Works quietly on assignment, making good progress and asks questions when necessary
Innovation & creativity	Thinks laterally and derives new solutions from previously unrelated items.	Applies personal experiences to formulate new and different ways of attacking problems.	Makes new patterns of materials, words, or ideas
Technological literacy	Able to respond rationally to ethical dilemmas caused by technology	Able to value the benefits and assess the risks associated with technology	Understand how technological systems are designed, used and controlled
Critical thinking	High ability to think and reason	Inquiring and discovering information; then appraising the evidence	Identifies errors in information and processes
Common sense	Displays an upbeat—think before you do mentality	Considers possible outcomes for own actions	Polite & articulate individual who profits from learning.
Teamwork	Demonstrates an effective ability to listen, respect, & persuade others in a cooperative manner.	Questions and discusses approach with other team members	A keen willingness to assist others while respecting their work and personal space.
Attitude	Demonstrates an upbeat, polite and responsible disposition.	Assists others when called upon	Sees the positive in most tasks/activities
Decision making	Takes consistent action toward attaining preset goals by utilizing time	Varies action toward goals therefore lowering end results	Demonstrates action toward various goals.

Table 7. Character traits Rubric (Adapted from Kirchoff, 1996)

	3	2	1
Courtesy	Treated each member with complete courtesy and respect at all times	Treated each member with courtesy and respect most of the time	Courtesy and respect for others was lacking
Rules followed	Responded well to all rules	Responded well to rules most of the time with few lapses	Seldom stayed within the rules on her/his own

Table 7. continued

Performance of task	Worked diligently to do her/his part of the task	Needed some prompting to stay on or complete task	Caused confusion due to lack of staying on task
Cooperation with team members	Cooperated with team at all times to make completion of task smooth	Cooperated with team most of the time but needed reminding	Rarely cooperated with team without constant reminding

construction of rubrics takes time, but the wheel does not need to be reinvented for every task. There are effective rubrics for a wide range of technology processes and tasks that can be found on the internet and in curriculum documents. Rubrics help take the "guesswork" and mystery out of assessment by communicating clear performance criteria. They provide levels and standards of performance to guide both students and teachers. Rubrics provide criteria for teachers to back-up their marks and grades in an objective way. They also provide a clean way of shifting from letter grades to comments for communicating to parents. Rubrics are indispensable for assessing cognitive process such as problem-solving.

Table 8. Web page design Rubric (Adapted from BC MOE, 1996)

Outstanding	· The document incorporates the correct use of HTML-plus, enhanced HTML, or both; is free of structural and syntactical errors; and uses coding that is clearly and consistently formatted. · Links are among the best available on the selected theme, and all sites are listed clearly and concisely to facilitate their use. • The page is highly visually appealing.
Good	· The document is free of structural and syntactical errors, and coding is clearly and consistently formatted. · Links are useful and well documented. • The page is visually appealing.
Satisfactory	· The document is free of major structural and syntactical errors, and the coding is understandable. · Links are functional, and the page contains basic documentation. • The page is free of major visual formatting flaws.
Less than satisfactory	· The document contains major structural or syntactical errors, and coding is difficult to interpret the page is difficult to use or does not function. · Some or all links are not functional, or the page does not contain documentation on the links. • The page has major visual formatting flaws.

Problem-Solving

While problem-solving is one of the most heavily emphasized methods in technology studies, it is a challenge to authentically assess. Should we assess the intellectual processes used to solve problems, the creativity applied in resolving the problems or the solution to the problem itself? Should we assess the process, product or both? Should we assess qualitative issues (complexity and how it was solved) or quantitative issues (how fast or how many?), or both? Can we develop criteria to judge the quality of problem-solving?

There are generally three types of problems. Simple problems are highly structured and usually have a correct solution. They can be represented in a straightforward way. Applied problems are structured but require the drawing together of diverse procedures and background information. The form of the solution is defined or the sense of the form is implicit. Complex problems are loosely structured and open ended. They may require the development of new processes and strategies to solve. The process required may be ambiguous to use, there may not be an established or correct answer and the solution may be difficult to represent. How can we assess applied and complex problems?

One helpful way of authentically assessing problem-solving is to reduce it to four performance aspects. Engagement refers to the extent to which the student identifies something as a problem and becomes engaged in solving it. Background knowledge refers to the extent to which the student accesses and uses appropriate information. Process refers to the extent to which the student knows and can use appropriate problem-solving strategies. Representation refers to how effectively the student can communicate his or her solution and the thinking and processes behind it.

For the most part, the students' interests in solving a problem define whether a problem exists. When the teacher sets the problems, low levels of engagement suggest that the students do not identify the problem as a problem. It would be inappropriate to assess problem-solving behavior for simple problems. When the students identify something as a problem, then it is appropriate to assess problem-solving behavior. As problem solvers go about the business of resolving problems, they access and analyze prior knowledge to bridge the gaps between what they know and want to find out. The background knowledge necessary to solve a problem is extremely important and students will demonstrate the degree to which they are accessing the information needed. Effective problem-solving involves recognizing what to do, when to do it and how to do it. Problem-solving competence and maturity reflects a growing repertoire of strategies. This may mean that students draw on certain problem-solving methods (Chapter V) or particular reasoning strategies (Chapter II). Teachers typically introduce strategies for their students to apply and may intervene to support their students' development in the course of a problem. The communication of problems and solutions need not be written. There are various means of representation that can be used (e.g., digital animation, drama, images, structures). Students may arrive at the same solution to problems and choose to represent the solutions in different ways (BC MOE, 1995a). Once technology teachers understand these four aspects of problem-solving, they can develop rubrics for authentic assessment (Table 9).

Different levels for each aspect or concept can be developed to differentiate novice from mature and advanced problem solvers. The key to the authentic assessment of problem-solving lies in its reduction to significant aspects and their elaboration within a rubric, such as in Table 7. If we assess engagement, background knowl-

Table 9. Problem-solving Rubric (Adapted from BC MOE, 1995a)

Problem Aspect / Level	Low	Average	Advanced
Engagement · Interest in problem. · Involvement in problem. · Defines problem.	· Little. · Off-track. · With difficulty.	· Wants to solve. · Seeks/needs reinforcement. · With some difficulty.	· Active/thoughtful. · Independent. · Clarifies/copes with ambiguity.
Background knowledge · Content knowledge. · Focus range. · Applies techniques (rules, methods, plans, algorithms). · Transfers knowledge.	· Many gaps. · Narrow. · Seldom. · None.	· Some gaps. · Narrow/ some new information. · May apply some. · Makes generalizations.	· Complete. · Finds missing info. · Applies techniques. · Uses knowledge from many situations.
Process · Recognizes what to do. · Applies strategies. · Uses alternatives. · Monitors progress.	· Unsure/loses sight of problem. · Uncertain. · Resistant. · No.	· Uncertain of approach. · Yes, can't explain why. · Seeks suggestions/ gets frustrated. · Seeks help.	· Capable/changes when necessary. · Clarifies ideas. · Explores unique procedures. · Functions independently.
Representation · Restates the problem. · Communicates about process. · Organizes solution.	· With difficulty. · With difficulty. · Partial/disorganized /incorrect.	· Restates some features. · Reflects on some processes. · Complete, but not thorough.	· Communicates details. · Describes thinking processes. · Thorough & organized.

edge, process, and representation, we can develop a comprehensive approach to the assessment of problem-solving.

Tests and Measurements

Tests refer to a broad group of instruments and practices for assessing and measuring action, cognition and emotion. There are tests of educational knowledge, dexterity, fitness, intelligence, racial prejudice and religion preference. There are medical examinations and tests, and psychological tests of emotional and mental health. On the Web, we can find tests for just about anything imaginable. Educational tests refer to a wide range including exams and quizzes, scales that deal with affective issues and feelings, as well as a range of tests of dexterity, speed, strength and skill. These may be administered in an oral format, written paper and pencil formats, computer automated format, or they may require physical manipulation and movement. A psychologist, teacher, or expert of some sort is needed to administer some of these while others can be self-administered. *Measurement* means the quantification and qualification of traits of action, cognition, and emotion as well as to the methodological and statistical techniques used in quantitative and qualitative assessment. Measurement may mean simple measures of central tendency (mean, median, mode), measures of item discrimination in an exam, or quite complex statistics that allow for confident, diagnostic and prognostic predictions of failure and success, criminality and recidivism, or disease and wellness. This section is limited to simple aspects of tests and measurements in educational practice with the focus on teacher-made tests.

Within our context of authentic assessment, tests and measurements are effective tools to supplement, rather than dominate, an assessment system. Authentic assessment does not mean that tests are inauthentic. Rather, authentic techniques establish a context and role for quizzes and tests that differs from their role outside of a system of authentic assessment. Testing was traditionally used for quality control such as maintaining rigor and standards of the discipline or of achievement, for sorting students according to test scores, and for the sake of preparing students for the testing processes of higher education. This last use is reductionism, where C&I are reduced from the practices and entrance requirements of universities. Other than this, the traditional uses of tests are important. Again, tests and measurements play a complementary rather than dominant role in authentic assessment. Only secondarily ought they serve the administrative purposes that dominate traditional uses. Remember, our first criterion for assessing our assessment and measurement techniques is that they primarily serve the learning process.

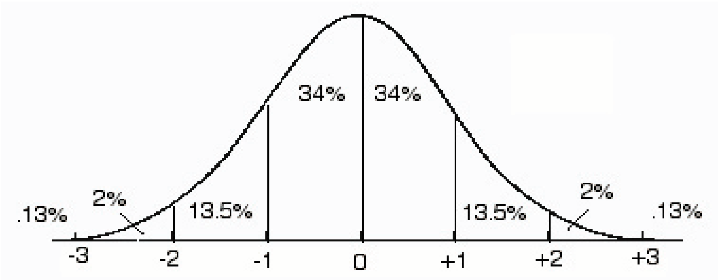
Tests and measurements play powerful roles in the lives of our students. They have the power to make or break students for life. Students who are diagnosed with a learning disability and treated with some therapeutic program of drugs and remediation will always carry this trauma. Students who are consistently belittled in the face of tests and measurements will internalize the frustrations of failure. Tests and measurements also have the power to help us monitor and direct the learning of our students—to detect deficiencies and proficiencies and be a positive force in their lives. With this type of power come responsibilities. Teachers have the responsibility to produce tests that are professional and of the highest quality. The National Council on Measurement in Education (1995) advocates, among others, the following responsibilities in a code of ethics:

- Ensure that assessment products and services are developed to meet applicable professional, technical, and legal standards.
- Develop assessment products and services that are as free as possible from bias due to characteristics irrelevant to the construct being measured, such as gender, ethnicity, race, socioeconomic status, disability, religion, age, sexuality, or national origin.
- Plan accommodations for groups of test takers with disabilities and other special needs when developing assessments.
- Use copyrighted materials in assessment products and services in accordance with the law.
- Protect the rights to privacy of those who are assessed as part of the assessment process.
- Develop reports and support materials that promote the understanding of assessment results.

One of the greatest challenges in tests and measurements is dealing with variability and diversity. Given the wide range of learning styles that students bring to education, we are challenged to assess in ways that respond to this wide range. In other words, if we are providing a wide range of activities that respond to different learning styles, then we necessarily owe it to our students to use assessments that allow for multiple intelligences and learning styles. Tests generally tend to force all students into a single learning style. Hence, as indicated, we should situate tests in a larger context of authentic assessment. This helps us to respond fairly to different learning styles but we are still confronted by the challenge of variance and diversity. The model of variability and diversity in tests and measurement is the Bell Curve or Normal Curve (Figure 1).

The Normal Curve was developed during the 19th century to account for the dispersion and distribution of certain biological and psychological traits. It is a form of regularity based on probability and random variation. If we measure the same trait of many cases that have differences caused by random variation, the frequency of

Figure 1. The normal curve



similarities and differences in this trait will take the shape of a normal distribution. To simplify, the concept is that if we take a measurement of some trait (e.g., height, weight) of a large number of people in a population, about 68% would be more or less average, about 13.5% would deviate one standard deviation above and below the norm, about 2% would deviate two standard deviations above and below and .13% three standard deviations. A standard deviation is a measure of distance from the mean. The point is that in populations and other social phenomena, about two-thirds would be around the average and the rest would be some distance higher or lower.

The normal curve presented a model for comparing students to a norm or mean. In the 1910s and 1920s, psychologists suggested that intelligence test scores were distributed on a normal curve—most students were average, some were sub-average or moron and feeble-minded, some were above average or gifted and the well-above average were genius. They also noted that the Stanford Achievement Test (SAT) sorted students according to the normal curve. A score of 500 on the SAT was and still is the average. From this practice of norm-referenced assessment, some psychometricians argued that the normal curve was invaluable for comparing students to national and international norms. The problem was that administrators eventually wanted their districts and schools to represent normal distributions and teachers adopted the mentality that their classes were mere samples of the normal distribution. The problem was that they overlooked one important detail of the bell curve: To approach a normal distribution we need the scores of thousands or hundreds of thousands of students taking the same test. Otherwise, we are dealing with small samples (i.e., 30 students in a class) and have to settle for so-called abnormal distributions. In fact, the "well curve," high on the ends and low in the middle, is a common distribution for classes as well as the size of business organizations. So we are left with the question of how do we know whether we have created a good test? If we can no longer use the normal curve as a model for our tests, where about 68% of our students would receive C's, 13% would get B's and D's, and about 3% would fail and 3% would get A's, how do we know if we have a good test? What determines an effective test?

Table 10. Principles of test design

1. **Validity:** Does the assessment process or scale really measure what it purports to measure (i.e., design capability by sorting shoes)? Does it look authentic or seem appropriate to the students (**face validity**)? Does it address and cover what was taught (**content validity**)? Does it discriminate to assess the students' actual levels of achievement and performance (**concurrent validity**)? How well does the assessment or scale predict how a student will perform at a certain task in the future (**predictive validity**)?
2. **Reliability:** Will I get the same results if I assessed the students again with the same scale, or if someone else assessed the students? To have validity, the assessment or scale must have reliability.
3. **Objectivity:** Do the items of assessment processes and scales offer a clear interpretation for the students?
4. **Discrimination:** Does the assessment process or scale lend itself to the challenge of identifying different levels of comprehension or performance?
5. **Comprehensiveness:** Does the assessment or scale sample the full range of content within the specified unit or course?
6. **Usability:** Is the assessment process or scale designed so that it can be administered and scored with relative ease?

Constructing Effective Tests

Simply put, a good quiz or test is one that measures what it is supposed to measure. In our context of authentic assessment, a good test is one that is complementary to learning and instruction. Good tests are interdependent with C&I. Good tests are those that discriminate (between those who know their stuff and those that do not) but whose value is not dependent on discriminating to the point of a normal distribution. Good tests are moderately difficult and practical to administer. We judge teacher-made tests by how well they enhance learning and instruction. Teacher-made tests that adhere to general principles of test design will always be the best tests. Tests are extremely valuable for monitoring student progress, but must be carefully constructed with the principles of test design in mind to provide adequate feedback to students and teachers. There are seven general principles with which we judge tests: validity, reliability, objectivity, discrimination, comprehensiveness, and usability. Definitions are provided in Table 10.

The first step in constructing a good test is organization. Just as we need a blueprint in construction, manufacturing, and design, we need a test blueprint for constructing a good test. The test blueprint allows us to see the big picture (scope and sequence) while focusing on the logistics and pragmatics of the test itself. Test designers recommend that we create a grid or matrix with performance levels of our affective, cognitive, or psychomotor domain in columns and content or objectives addressed in our unit or course distributed among the rows (Table 11). If we include our entire outline of content or all our objectives in the rows—effectively our scope and sequence of content—we can then sample from the outline and tally the test items with levels that we want to test. Some content or objectives will be assessed through performances and portfolios. The blueprint provides a way of sampling what will be quizzed or tested. In Table 11, the content organizers from the ITEA's technology standards and the cognitive domain are used.

Once the blueprint is completed, the next step is determining the types of items that will be used in the test. The blueprint will serve two purposes at this stage.

Table 11. Test blueprint

Technology standards test	Performance Levels							
	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation	Total	Percentage
Content Outline	Number of Items							
Characteristics and scope of technology	2				1		3	
Core concepts of technology			2				2	
Relationships among technology and other fields	2						2	
Cultural, social, economic and political effects of technology						2	2	
Effects of technology on the environment				2			2	
Etc.								

Table 12. Types of test items

Selected response	Constructed response
• Multiple-choice.	• Completion.
• True-false.	• Fill-in-the-blank.
• Analogies.	• Forced-choice.
• Sequences.	• Vignettes.
• Matching.	• Rearrangement or continuity items.
	• Essay.

One, it provides a quick reference for constructing the test. Two, the content topics sampled in the blueprint will serve as the subtitles in the test. Rather than a random organization of test items, the items will be grouped by content. There are generally two types of items: selected response and constructed response.

Both types of items are challenging to write, and both have their place in assessment. The primary principles of test design tilt toward the student. In other words, we ought to construct tests with the students' best interest in mind. Most of us have taken tests where these principles were clearly not operative. Quite often, tests are constructed in the interest of the teacher. These types of tests were created in the last minute, tested for things that the teacher thought were important but seemed unimportant to the students, and were technically inadequate in terms of clarity, readability and subjectivity. These tests were invalid. This is precisely what we want to avoid. We want to create tests that the students feel are valid. Certainly teachers need to keep their own interests in mind, but there are constructive ways of doing this. Recall that usability, which works in the teachers' favor, is our sixth principle of test design. Techniques and guidelines of test design are guided by our six principles.

After constructing the test blueprint then next step is constructing the test. Good tests consist of four separate sections (Table 13). The first section is the title block, the second section is the answer column on the left of the page, the third section is for item directions and the fourth is the test item section. The title block provides the test title and the spaces for student information. Place directions for answering the type of items in the section at the top of each test item section. Group items by content and, on comprehensive tests, these sections ought to have a content heading. Reserve a column on the left side of the test for the student answers. This allows for ease of scoring on paper and pencil tests. English and Romance languages are read from left to right, and it is easier to read from your answer key to the students' answers from left to right. The example format from a cumulative, final exam for technology teachers elaborates these sections with details.

Keeping the overall design format of quizzes and tests in mind, we have to choose the types of test items to correspond with the levels and objectives to be sampled. Will we be using selected response or constructed response items, or a combination?

Table 13. Test sections

Test title & title block (Space for Student Name, Date, etc.)	
Answer Column	Item type directions True-false items Multiple choice items Matching items Completion items

Final Exam
Curriculum and instruction for technology teachers

Name:______________________________ Date:_______________________

General Directions: You will have 2 hours to complete this final exam. Please DO NOT use notes or handouts for the exam. **GOOD LUCK!**
100 Points Total

True-False: Choose the best answer. Circle "T" if the statement is true and "F" if it is false.

History of technology studies

T F 1. The British Arts and Crafts movement emphasized design for manufacturing.
T F 2. The audio-visual movement pre-dates the educational technology movement.

Demonstrating

T F 16. There is a single "best" sequence for demonstrating an application, tool, machine, or process.

Assessment

T F 59. In criterion assessment, good criteria are essential to judging the performance adequately.

Matching: Choose the concept that best matches the statement. Place the letter of the concept on the right next to the numbered statement on the left. Concepts CAN be used more than once.

Gender and technology studies

For Questions 64-77
____ 64. Approach such as "powder-puff" technology. A. Holistic

B. Equal Treatment
____ 65. Approach where girls are given extra help. C. Equal Output

D. Equal Access
____ 66. Approach where a teacher examines her or his practices

and disposes of projects that have questionable gender content.

Table 13. continued

____ 67. Approach where counselors remove barriers so girls

can take shop courses.

Multiple Choice: Choose the best answer. Circle the letter to the left of the option

Classroom management

97. When we say that teachers must model appropriate behavior and language, we mean that they ought to model

A) respect for students and guests in the workshop.
B) gender and racial equity.
C) skills without reinforcing gender roles.
D) ecological practice without appearing preachy.
E) All of the above

Writing good test items is a challenge, but if we have prepared the module, unit or course according to instructional design principles, the process of test construction can be quite smooth. If we have written an ample amount of objectives for the module, unit or course, stated them in assessable terms, and devised a test blueprint, the process of writing test items is straightforward. However, we have to attend to the techniques of item design. Guidelines and techniques for item construction are especially helpful (Sparzo, 1990). The following techniques for true-false, multiple choice, and matching items were provided by Davis and Spencer (2002) as shown in Tables 14, 15, and 16.

True-False Examples:

T	F	1. The Pelton water wheel is more efficient than the turbine.
T	F	2. A wheelbarrow is an example of a second-class lever.
T	F	3. A solar cell converts mechanical energy to electrical energy.
T	F	4. The steam engine is an external combustion engine.
T	F	5. A flashlight battery is a type of wet cell.

Table 14. True-false item techniques (Davis & Spencer, 2002)

Guideline	Explanation
• Use vocabulary that corresponds to the test material and is appropriate for the targeted age level.	True/False items are very straightforward items. These items serve to measure recognition and recollection of facts.
• Test one idea at a time. Divide compound ideas into two or more items.	
• Avoid specific determiners such as: *only, exactly, precisely, absolutely.*	These terms indicate circumstances that have no exceptions (these circumstances are very uncommon). Thus, the correct response given this pragmatic principle is to mark the item false.
• Avoid using terms that suggest an indefinite amount or degree, such as: *small, large, a long time ago, often, seldom, high, low, sometimes, usually, typically, and generally*.	These terms lead to challenges of their meaning which reduces the consistency of responses to the item. This lowers the validity of the test item.
• Avoid stating the test item in a negative sense by using *no* or *not.*	The negative phrasing complicates the logical structure of statements making the item unnecessarily difficult. If the statement cannot be worded positively, emphasize the negative terms by underlining or bolding.
• Use popular misconceptions as false statements.	
• Construct true-false items that require the use of introductory materials such as maps, graphs, or readings.	
• Have the students correct the false statements by changing them into true statements.	

Multiple choice example:

1. AutoCAD drawing files are typically saved with what type of file extension?

A. dwg

B. gif

C. mov

D. cad

E. jpeg

Table 15. Multiple choice item techniques (Davis & Spencer, 2002)

Guideline	Explanation
• The multiple choice stem needs to present one problem to the student before the options are considered.	A student should be able to formulate the answer before reading the options. This can be achieved by clearly indicating the topic of the test item using clear, simple, and direct language. The stem should be in the form of a specific incomplete statement or a direct question.
• Avoid writing stems that contain extra information as an introduction to the question. The stem should only include the question or the incomplete statement.	
• Restrict the use of negative terms in the stem.	Students may not notice the use of the negative term in the question. If the statement cannot be worded positively, emphasize the negative terms by underlining or bolding them.
• Construct stems that require the selection of the *best* answer when each of the options contains elements of correctness.	Multiple choice tests should measure a level of comprehension beyond pure memorization. Construct stems that require the student to use higher order thinking, not just a simple recall of the facts, to answer the item correctly. These questions are more difficult and discriminating than questions that ask for the recall of a single fact.
• Each distracter should have about the same number of words as the correct option.	One option that is longer than the rest often indicates the correct answer to the student.
• Make all distracters plausible.	
• Do not repeat wording or common elements from the stem in the correct option.	
• Make sure the stem is grammatically consistent with all of the options.	Students may reject options which are grammatically incorrect with the stem without truly knowing the content.
• Avoid using overlapping distracters.	
• Avoid the use of indefinite terms such as *usually* and *generally* in the options and distracters.	These terms indicate circumstances that have many exceptions (these circumstances are very common). Thus, the student may be cued into selecting the option with this term in it as the correct answer without truly knowing the content.
• Avoid the use of absolute terms such as *never* and *always* in the options and distracters.	These terms indicate circumstances that are without exceptions (these circumstances are very rare). Thus, the student may be cued into ruling out this option as the correct answer without truly knowing the content.

Table 15. Multiple choice item techniques (Davis & Spencer, 2002)

• Avoid using "all of the above."	Recognition of one wrong option eliminates "all of the above." Recognition of two right options identifies "all of the above" as the answer, even if the other options are completely unknown to the student.
• To increase item difficulty, include "none of the above" as a final option.	
• After the options are written, vary the location of the answer.	

Matching example:

_____1. *Match Parts of a DC Motor with Diagram (Below)*

_____2. A. Brush

B. Commutator

_____3. C. Power Supply

D. Armature

_____4. E. Field Magnet

_____5.

_____6.

Table 16. Matching item construction techniques (Davis & Spencer, 2002)

Guideline	Explanation
• Include specific, clear directions for the students.	
• Use only items that share the same foundation of information.	Unrelated topics included in the same matching item may allow for obvious matches and mismatches.
• Avoid using matching items that require sentence completion.	This technique provides the student with grammatical clues, which enable them to complete the sentence correctly without needing any knowledge of the topic.
• Write more responses than stimuli for each matching item.	This will help prevent the students answering the items by the process of elimination.

Table 16. continued

• The stimuli should be numbered and listed in a column on the left, while the responses should be lettered and laid out in a column on the right.	
• The column of stimuli on the left should set the question clearly.	
• The items for a matching exercise should be listed on one page.	This prevents unnecessary confusion created by flipping back and forth between pages.
• Limit the list of stimuli to fewer than 8 in order to keep the number of matching items brief.	

Grading, Marking and Reporting

Administrators, school boards, and teachers all have responsibilities to make sure that guidelines for student reporting are followed. Schools have very formal processes for reporting student progress. Most require three written reports (report cards) during the year, including one at the year's end, and at least two informal reports. Teachers are responsible for reporting for a number of reasons, including: (1) provincial or state legislation and policy for reporting on student progress; (2) accurate assessments for parents to comprehend their children's performance; (3) support of classroom learning; and (4) policy related to students with special needs. Additional reasons are commonly used for reporting at various grade levels. For instance, percentages and letter grades are required at the junior and senior levels and detailed literacy reports at the primary grades.

Match Parts of a DC Motor

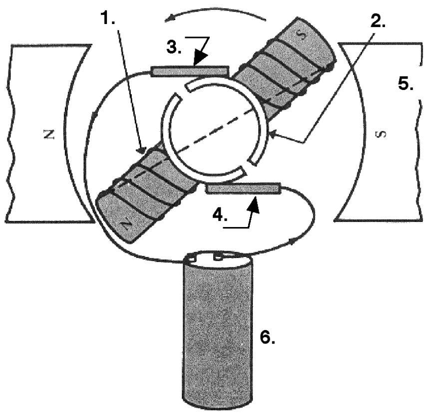


Table 17. Letter grade percentages and interpretations (Adapted from BC MOE, 1995b, p. 8)

A	B	C+	C	C-	F
86 - 100	73 - 85	67 - 72	60 - 66	50 - 59	0 - 49

A The student demonstrates excellent or outstanding performance in relation to the expected learning outcomes for the course or subject and grade.

B The student demonstrates very good performance in relation to the expected learning outcomes for the course or subject and grade.

C+ The student demonstrates good performance in relation to the expected learning outcomes for the course or subject and grade.

C The student demonstrates satisfactory performance in relation to the expected learning outcomes for the course or subject and grade.

C- The student demonstrates minimally acceptable performance in relation to the expected learning outcomes for the course or subject and grade.

F Failed or Failing. The student has not demonstrated, or is not demonstrating, minimally acceptable performance in relation to the expected learning outcomes for the course or subject and grade.

I In Progress or Incomplete. The student, for a variety of reasons, is not demonstrating minimally acceptable performance in relation to the expected learning outcomes.

Structured written reports to parents or guardians must be direct and use plain language. Written reports must follow the specific requirements for reporting student progress at each grade level. Comments in a student progress report describe, in relation to the curriculum:

- What the student is able to do.
- Areas of learning that require further attention or development.
- Ways the teacher is supporting the student's learning needs (and, where appropriate, ways the student or the parents might support the learning).

Each school year, teachers typically provide parents with a minimum of two informal reports. Informal reports usually describe the same things a formal report describes. However, the informal reports are commonly oral. They provide an important link between home and school and can be accomplished in a variety of ways, such as telephone calls, interim reports (written or oral) or conferences (parent-teacher, three-way, student-led, etc.). Most schools ensure that parents have the opportunity to meet with teachers for a conference at least once each school year. Teachers normally keep a record of each informal report noting the date of report, type of report and topics(s) of discussion.

In most school districts, letter grades are assigned to courses in grade 4 and higher. The successful completion of courses in grades 11 or 12 usually requires a minimum of a C-. Letter grades should be criterion-referenced throughout the students' courses in grades 4-12. In other words, teachers ought to create rubrics to clearly inform the students what the criteria are and mean for an A or B or etcetera. The numerical percentages and interpretations associated with letter grades are generally as follows in Table 17.

Summative assessments that are written in formal reports to parents or guardians must be, and usually are, based on a series of formative assessments. These formative and summative assessment data must be qualitatively and quantitatively analyzed with any number of means. For summative marks that must be in a quantitative format (percentages), formative assessments must be quantified throughout the term. Teachers assign a weight, indicating importance, to various performances (e.g., artifacts, cooperation, images, participation, portfolios, presentations, problem-solving, projects, quizzes, reports) to use for assessment. Some of these may account for as little as 5% or 10% of the final grade. Others, with a weight indicating importance, will account for as much as 40% or 50% of a grade. If the teacher is providing individual points or marks, then s/he may allot 10 marks for the minor performances and 35 marks for the major performances. The total marks allotted for all the performances in this case would tally to 100 marks. This is one way of dealing with weights. The assessment component of the teacher's outline for the course would look like this:

Module #1- 5 marks	Participation- 15 marks
Module #2- 5 marks	Project #1- 15 marks
Quiz #1- 10 marks	Project #2- 15 marks
Quiz #2- 10 marks	Portfolio- 25 marks
	Total= 100 marks

Here, a student who got 10 marks for the modules, 15 out of 20 for the quizzes, 13 for participation, 20 on the projects, and 20 for the portfolio would receive a summative or final mark of 78 or 78%. This is a B on our typical grade point and letter scale. Or, the teacher may choose to mark all assignments or performances on a 10 mark or 100 mark scale. The rubrics for this teacher would divide the levels of criteria into divisions of 10 or 100. The same teacher's assessment component on the course outline would look like this (weights are noted by percentages):

Module #1- 5%	Participation- 15%
Module #2- 5%	Project #1- 15%
Quiz #1- 10%	Project #2- 15%
Quiz #2- 10%	Portfolio- 25%
	Total= 100%

To calculate final marks, the teacher would have to write an equation or formula for a calculator or spreadsheet. The equation would be written as follows:

Total= (Item1 x .05) + (Item2 x .05) + (Item3 x .10) + (Item 4 x .10) + (Item5 x .15) + (Item6 x .15) + (Item7 x .15) + (Item8 x .25)

On the scale of 10 or 100 for each item, the same students above could have received 10 out of 10 for each of the modules, 9 out of 10 for each of the quizzes and for participation, and 8 of 10 (80%) for each the projects and the portfolio. The final mark would be 7.75 or 78%. Some psychometric experts suggest that in order to properly account for the variance within each of the assessment items, the individual items for each student should be transformed into z scores (normalized). Then, they say, the weights carried by each individual item will be more accurately calculated into the equation. This can easily be done with a spreadsheet but is overkill for most teaching situations.

Rubrics made the scoring of performances (e.g., artifacts, cooperation, images, participation, portfolios, presentations, problem-solving, projects, reports) easier for teachers. Marking, grading and scoring remains a very tedious process, nevertheless. Teachers who mark portfolios know all too well the numbers of hours spent reviewing and deliberating on entries within the individual portfolios. The marking of the artifacts from art or technology assignments can take days or weeks. The same goes for the marking of reports. In the late 1990s, software programs with artificial intelligence appeared on the market for marking essay questions and reports. Teachers who automate their quizzes and tests by placing them online, use courseware quiz scripts, or use Scantron answer forms that can be scanned and automatically corrected, benefit from the ease with which items can be marked and graded. Essay grading software is also readily available. There is great value in using computers for the testing process. New teachers should take every opportunity that they can to ease the grading process for themselves.

During the 1980s, a number of applications for grading, or automated grade books, appeared on the software market. By the late 1990s, many schools required their teachers to use a digital grade book adopted by their district. This made the submission and maintenance of student records much easier in many ways. On the other hand, it has forced teachers into somewhat uniform grading systems—they had to alter their grading practices to work with the digital grade book. The adoption of school-wide and district-wide digital grade books has also opened up the teachers' assessment practices to parents in ways never dreamed of thirty years ago. Parents and students now have access to browse the grade books via the web at anytime during the year.

Software grade book programs can range from glorified spreadsheets with simple functions to large databases with AI and plug-ins for a variety of other applications. The simplest grade books allow teachers to take care of the basics such as setting up classes, entering assignments, selecting grading methods used for grade calculation, and printing simple progress reports and reports. The more sophisticated programs offer the ability to create graphs of student progress, monitor attendance, record notes about student work, track parent contacts, print reports and link into school and district databases. Some allow for the use of a Personal Digital Assistant. Available digital grade books include Class Mates Grading Tools for Windows, 1st Class Gradebook, Grade Machine and Grade View, Gradebook 2, Gradechecker, Integrade Pro, MicroGrade, Parent Internet Viewer, Teachers Assistant Professional and ThinkWave Educator.

Grade Inflation

Veteran teachers who have been in the schools for thirty or forty years often note the changes in grading patterns over the course of their careers. "Courses were more rigorous," they note, and their grading practices were tougher thirty years ago. Everyone is easier on the students. Grading is one symptom in the larger pattern of softness. Work that would have received a "C" thirty years ago receives a "B+" or "A" in schools today, they note. By definition, grade inflation is the rise in the average marks of students over time. It is the skewing of the normal curve toward the upper end of the scale. It is the overly generous awarding of marks for under achievement. It results in the increase of student grade point averages (GPA) over time. Is grade inflation really an issue?

Researchers interested in grade inflation usually compare SAT test scores over time with GPAs over time. In recent studies, the records of 2.6 million students were examined. The researchers often compare affluent districts with poverty-stricken districts and schools. They consistently find that the advantaged schools rank higher in standardized test (ACT, SAT) scores and but, on average, have lower GPAs than the disadvantaged schools. The students in the disadvantaged schools get higher marks and grades than the advantaged students but score lower on the international and national tests. This irks some analysts. "Grade inflation is particularly extensive in high schools with a high percentage of disadvantaged students," M. Donald Thomas, an education advisor, reported to a national audience of school administrators in the U.S. He drew from this the conclusion that "this indicates clearly that expectations for students are very low, and standards do not match those of testing agencies." Does this indicate low standards? Is it fair to make these types of comparisons? Do we want disadvantaged students to *appear* to be low achievers and, in effect, dumber on all educational indicators? Could it be that students who score lower on the ACT and SAT tests, which deal only with English, math and science, actually excel in the subjects that are not tested on these tests (e.g., art, home economics, technology)?

How do we know if our students' grades are inflated next to our colleagues' students? How do we know if we are inflating our students' grades? Some analysts insist on the normal curve. They suggest that in any course, about 68% of students ought to get C's, about 14% ought to get D's and 14% ought to get B's and about 2% should get A's while another 2% should fail. Other analysts suggest that there is no magic bullet with which to curb grade inflation or keep it in check. And still others emphasize the importance of authentic assessment. If we authentically assess our students, they note, then grade inflation is not an issue. Grading, they insist, ought to inform instruction and actually help students improve their performance. Can we have high expectations and standards, and at the same time award the majority of our students with A's and B's?

Questionnaires and Scales of Technological Literacy

The Holy Grail for researchers in technology studies is a reliable, valid and standardized scale of technological literacy. In Chapter VII, we defined technological literacy to include action, cognition and emotion. The challenge is to create a scale that can be used nationally and internationally for comparative research and policy. In Chapter VIII we asked what *should* all students know about technology? Scales for research and policy ask what *do* students know about technology? Both questions are significant for researchers and teachers. While a number of scales of technological literacy have been constructed, none have been universally accepted. The difficulty of defining technological literacy, the changing nature of technology, and the lack of funds all contribute to the eventual success and obsolescence of a single, universal scale. With the ITEA's and ISTE's standards projects, a standardized scale of technological literacy is immanent. To date however, researchers have been more likely to use scales that measure attitudes than those that measure literacy (Hoepfl & Lindstrom, Forthcoming).

For example, in the mid 1980s, Marc deVries of Eindhoven University along with E. Allen Bame and William E. Dugger of Virginia Tech created a scale to measure grades 8-12 students' attitudes and values toward technology. This became known as the *Pupil's Attitudes Toward Technology (PATT) Scale*. The PATT Scale continues to be used and remains one of our most reliable tools for comparative measures of students' attitudes and values toward technology. The most common version of the PATT Scale consists of 100 Likert type items. The first 11 items are used to collect demographic information for the individual students. The remaining items deal with issues that force students to form an opinion (although there is a "neutral" option). Sample items include the following:

Agree	Tend to agree	Neutral	Tend to disagree	Disagree

12. When something new is discovered, I want to know more about it immediately.
18. I would like to know more about computers.
24. A girl can become an auto mechanic.
40. I think visiting a factory is boring.
43. To study technology you have to be talented.
69. With a technological job your future is promised.
76. In my opinion, technology is not very old.
97. Technology has little to do with daily life.

The PATT Scale is similar to scales of environmental values, militarism-pacifism, and the politics of technology. However, these latter scales are inherently more political. For instance, a popular scale on environmental values includes the following items:

Slightly agree	Agree	Strongly agree slightly disagree	Disagree	Strongly disagree

15. We're advancing so fast and are so out of control that we should just shut down and go back the way it was in colonial times.
23. People should pay the environmental costs of the things they buy. Products should be taxed depending on their effect on the environment.
37. We don't have to reduce our standard of living to solve global climate change or other environmental problems.

117. As new technologies become available that are less environmentally damaging, companies will naturally want to adopt and use them.

These scales are effective tools for social science research. But they are not just for university researchers. More and more teachers are involving themselves in research, mainly through action research programs. Action research is research that is directed at resolving immediate problems or policies that teachers face. Teachers with minimal capabilities in tests and measurements are feeling empowered to construct questionnaires and scales to investigate their students' attitudes and knowledge of technology. Some are adopting the validated scales such as PATT while others are constructing their own.

The key to constructing questionnaires and scales is to write items that provoke students to form an opinion and make a decision on something of value. Items that push students toward the extremes on a Likert scale are generally the best items. Some researchers recommend removing the neutral option in the middle. However, we must remain sensitive to cultural factors related to our students. Aboriginal peoples, for instance, tend to be reluctant to publicly express extreme opinions.

Likert type items are distinguished by the fact that they are assertions rather than questions. The respondent's task is to indicate the degree to which s/he agrees or disagrees with the assertion. Instead of having students explain their positions on issues, Likert scales force the students (or research participants) to respond to an issue or positions already formulated as an assertion. The use of Likert items allows for a quantification of responses and comparisons among groups. The key is to word the Likert items in very simple terms. Both negative and positive assertions are made to encourage respondents to deal with the content of the assertions rather than falling into an automatic response pattern. Typically, responses to the Likert items form "response sets" that allow teachers and researchers to assess where students stand on a range of issues. The response set helps researchers in determining that if respondents take a certain position with one issue they will take a related position on another issue.

Evaluation

The connotation of evaluation is that it involves inquiry that explores a characteristic, event, program or system in order to make a judgment on its merit or worthiness. However, there are actually four possible orientations to evaluation: (1) goal-attainment, (2) judgmental, (3) decision facilitation, and (4) illuminative. Goal-attainment evaluation is objectives-driven and the goal is to determine the extent to which intended outcomes are achieved. Judgmental evaluation means that a judgment is made on the value, or worth, of an endeavor or personnel based on external criteria. The judgmental orientation may focus on the professional judgment of the evaluator, as in a formal professional review system such as accreditation. Or a group of evaluators may judge the character of a leader by using prepared leadership evaluation scales. Decision facilitation evaluation typically means that evaluators do not personally assess merit or worth. Instead, they limit their role to gathering information for a decision-maker who will determine merit or worth. Illuminative or naturalistic evaluation is participant-oriented and focuses on the issues identified as important by stakeholders such as administrators, program staff, and students. The goal is to document the realities of individuals who experience the program first-hand. Adversarial approaches attempt to provide a balanced view by investigating different sides of issues, as represented by different participants. This goal is to generate opposing points of view within the overall evaluation process (Ruhe, 2003).

Neither assessment nor evaluation is limited to students. Student teachers are formally evaluated throughout their student-teaching practicum at least eight times and also go through a final or summative evaluation. New teachers go through a series of evaluations prior to receiving a form of tenure or a full-time appointment within their district. The evaluations may occur twice per year for the first three years of practice. The key to evaluation is preparation. Do not get caught off guard. Surprise evaluations are rare, so there is always time to prepare for an evaluation. Teacher evaluations are often high stakes, as they may determine career stability or salary raises. When you have time to prepare, you have time to prepare to look your best. Choose lessons and demonstrations for your evaluations that place attention on your strengths. Use lessons that you are familiar with and have practiced.

Most evaluations of teacher practices involve judgmental and decision-making orientations. Advisors, peer teachers, and administrators make the formal evaluations. Evaluation forms may be anecdotal checklists that resemble rubrics or open-ended to allow for free-flowing narrative. For instance, the anecdotal evaluation scale at the University of British Columbia (UBC) involves forty criteria by which student teachers are judged. Evaluation, including the evaluation of student teaching, is an extremely serious, and usually political, process. Similar to the authentic assessment of students, where they are given the criteria well ahead of the assessment, it is in your best interest to acquire the forms or scale with which you will be evaluated.

Like assessment, evaluation should be fair and should inform the process of improvement. Evaluation requires that deficits be candidly and clearly communicated in a constructive and timely fashion so that they can be eventually overcome. Administrators may have the upper hand in the evaluation of programs and personnel, but is it also common for teachers to evaluate their administration. In fact, the evaluation of leadership is an extremely active practice within the discipline of leadership studies (Wenig, 1995). Many leadership evaluation scales are designed to determine whether individuals have the "right stuff" to lead organizations. Other scales are similar to teacher evaluation instruments and allow for a deep analysis of the issues of organizational leadership. For example, one popular scale begins with the following items (SyberVision, 1993):

(-)		(+)	Score
1. Weak sense of purpose	1 2 3 4 5 6 7	Strong sense of purpose	____
2. Gives up easily	1 2 3 4 5 6 7	Very persistent	____
6. Unable to attract others	1 2 3 4 5 6 7	Magnetic, draws others	____
10. Self-ambitious; focused on own wants	1 2 3 4 5 6 7	Seeks to serve needs of others	____

As you can imagine, the evaluation of leadership is extremely sensitive. Subordinates often fear retaliation and opt for forms that allow for anonymous evaluation. In many cases, external teams are assembled to help mediate the process and provide an arm's length evaluation.

Courses, facilities, and programs are evaluated as well as personnel. Students in post-secondary institutions are quite familiar with course evaluations. Typically, the students submit each course and instructor to a process of evaluation. The most common evaluation scales for courses are forms with item "bubbles" to fill in with a dark pencil or pen. Course evaluation scales at most institutions are similar to each other. The sample items below from a popular scale will be familiar to post-secondary students and pre-service teachers.

0	1	2	3	4	5	6	7
Not applicable	Disagree very strongly		Disagree somewhat		Agree somewhat		Agree very strongly

0	1	2	3	4	5	6	7	
o	o	o	o	o	o	o	o	1. My interest in the course has increased because the way it was taught.
o	o	o	o	o	o	o	o	6. Course objectives were made clear.
o	o	o	o	o	o	o	o	14. This was an interesting course.
o	o	o	o	o	o	o	o	20. Course requirements were unclear.

There is also an opportunity for students to provide written comments. Both the scale and written comments are anonymous. Anonymity gives the students confidence to submit the evaluations without fear of retribution. In most countries, programs within post-secondary institutions are evaluated through a process of accreditation. Post-secondary technology programs are accountable to a range of governing bodies that require periodic evaluations.

Accreditation is the process whereby an association or agency recognizes an institution or program as having met certain qualifications or standards. It is generally a voluntary, non-governmental process of peer evaluation. This process holds institutions or programs accountable to certain, defined standards or criteria. Accreditation is often confused with certification: institutions and programs are accredited, and individuals are certified. Specialized or professional accreditors evaluate specific educational programs. For instance, there are specialized accreditation organizations for architecture, education, engineering, design, law, medicine, and the sciences. The Accreditation Board for Engineering and Technology (ABET), National Association of Schools of Art and Design (NASAD) and the National Council for Accreditation of Teacher Education (NCATE) are professional accrediting organizations that accredit programs in their respective disciplines. The ISTE, ITEA, and the Council for

Technology Teacher Education (CTTE) work with NCATE to accredit technology teacher education programs. The work of ABET, NASAD, and NCATE accounts for the accreditation of most post-secondary technology programs in North America.

Accreditation is a particular process of evaluation with specific evaluation items and criteria. This evaluation process requires to institutions to document the ways in which their programs meet standards regarding a range of items. For example, the ITEA/CTTE- NCATE process requires evidence for the ways that their students address items such as the following:

2.0 Possess the necessary depth and breadth in mathematics, science, and related disciplines to be able to successfully teach technology education.

3.0 Master teaching and technical skills appropriate to successfully teach the study of technology.

3.1 Possess knowledge about the development of technology, its effects on people, the environment and culture; and industry, its organization, personnel systems, techniques resources and products; and their impact on society and culture.

This process is supposed to influence provincial and state certification boards. In other words, the certification of technology teachers should be aligned with the accreditation requirements of the technology post-secondary programs. Theoretically, the provinces and states are supposed to hold teachers accountable who in turn would embody the contemporary standards and establish programs in the schools that are in line with state and accreditation standards. However, provincial and state certification programs often lag behind the accreditation process in the post-secondary institutions (Wiens, 1990).

Evaluation is an extremely important and ubiquitous process in business, education, and industry. In business and industry, facilities, personnel, and products are submitted to a regular routine of evaluation. In the previous chapter, we addressed the evaluation of curriculum materials, focusing on instructional design. The evaluation of facilities is covered in the next chapter.

Projection and Reflective Practice

In Chapter IX, we dealt with curriculum and instructional design. The decisions we make about "what should be learned?" and "how should it be organized for teaching?" are directly linked to assessment. In fact, authentic assessment originates with the ways that we answer to these problems of C&I. Most importantly, assessment is authentic when it informs the learning process. We began this chapter by setting up some rather problematic practices in technology studies. One example we used was the grading of artifacts rather than students—the grading of products over processes. We introduced three techniques of authentic assessment (portfolio, performance, and criterion-referenced assessment) to help us contradict the problematic practices. Portfolios and rubrics, which are used to cross reference criteria of performances, are extremely applicable to technology studies. Testing and measurements are redefined in the context of authentic assessment to serve the processes of learning and instruction. Designing effective tests is a challenging endeavor and guidelines for test design were provided. The processes of grading and reporting are also challenging. New, automated, and online modes of grading and maintaining records offer essential techniques for teachers and allow for the manipulation of large databases of information. We differentiated between assessment and evaluation by noting that assessment was associated with student progress and evaluation was associated with judgments on personnel, courses and programs. Accreditation and credentialing are particular forms of evaluation. In the next chapter, we will deal with the nuances of classroom management, facilities design, and safety. We will also address the challenges of special needs students and follow-up with specialized assessment and evaluation techniques.

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Chapter XI

Classroom Management, Facilities Design and Safety

Introduction

Classroom and facilities management require more than a series of techniques. Management and safety require a philosophy. Veteran teachers who “make it look easy“ have not perfected the techniques of management inasmuch as they have integrated certain techniques into a system and philosophy of C&I, assessment, discipline, facilities design, and safety. We can think of our combination of techniques and philosophies as flexible superstructure that complements our somewhat inflexible infrastructure of architectural units, devices, software, tools, and machines. The greatest amount of anxiety for new teachers tends to be over classroom management, and specifically the way that individual students are disciplined for incivilities. Rather than confronting incivilities, effective management and safety depends on *preventive* infrastructure and systems that are in place. This point cannot be stressed enough. Students will test new and veteran teachers alike. Veteran teachers may have the benefit of experience in dealing with incivilities such as bullying, but they rely on their infrastructure and systems of prevention rather than their reactive techniques. They know how to deal with individual incivilities but prefer preventive measures by setting a tone for acceptable classroom behavior. We will explore a range of techniques, including humor, for dealing with classroom behavior.

This chapter focuses on specialized classroom management techniques in technology environments, and specifically in technology laboratories (CAD, communications, electronics, information technology), studios (new media, radio, and television production), and workshops (manufacturing, production, transportation, etc.). The theme of the chapter is *prevention* and *discipline with dignity*, and a large range of classroom management issues that are specific to technology environments are addressed. Applications of theory to the micro-issues (routines, procedures) and macro-issues (philosophies, systems) of management are explained. Special needs and abilities are situated in the larger context of discipline with dignity and macro-management. We will also address the role of architectural aesthetics, ergonomics, form, and utility in the management of instruction and safety. A brief history of facilities design is provided and analyzed—from traditional workshops to modular labs to information technology labs, digital studios and learning plazas. In this new era of technology studies, the nature of facilities has changed. The main intention of this chapter is to provide support and assistance to develop a framework for professional preparation in classroom management, facilities design, and safety.

Components of Professional Practice

Most researchers identify classroom management as one of the most important components of professional practice and teachers' responsibility. The routines, rules and procedures that are put in place, the environment that the teacher designs, the

Table 1. Components of classroom management (Adapted from Danielson, 1996)

Creating an environment of respect and rapport
- Teacher interaction with students.
- Student interaction.
- Establishing a culture for learning.
- Importance of the content.
- Student pride in work.
- Expectations for learning and achievement.

Managing classroom procedures
- Management of instructional groups.
  Management of transitions.
- Management of materials and supplies.
- Performance of noninstructional duties.
- Supervision of volunteers and paraprofessionals.

Managing student behavior
Expectations
- Monitoring student behavior.
- Checking incivilities.

Organizing physical space
- Safety, cleanliness, and arrangement of facilities.
- Accessibility to learning and use of physical resources.

Maintaining accurate records
- Assessment.
- Completion of assignments.
- Student progress in learning.
- Safety records.
- Noninstructional records.

tone that is set, the modes of communication used and the system of discipline the teacher creates all impinge on classroom management. Some teachers go as far to suggest that content and methods are secondary to classroom management. In other words, until a safe, inspiring and respectful environment is created instruction is next to impossible. Curriculum and instruction are next to impossible without a system of classroom management that works. In the case of technology studies, the show of C&I does not go on until the stage of ethical and safe behavior is established through classroom policies. Of course, this is relative, as some teachers tolerate much more than others. Some teachers are willing to gamble with liability while others operate strictly by the book. Each teacher is responsible for a range of components of classroom management (Danielson, 1996) (Table 1).

Subjects requiring labs, studios or workshops (e.g., art, business, home economics, science, technology) place additional responsibilities on teachers. Classroom management within complex facilities is demanding but technology teachers would be the first to argue that the management of classrooms where students must remain seated most of the time opens up an entirely different form of challenges. Whether a lab, workshop or classroom, each component of classroom management ought to be considered prior to actually teaching. **Repeat:** Reactive management is no match for proactive management. Prevention is the operative word.

Code of Ethics

Professionals, such as engineers, lawyers, nurses, and teachers are governed by codes of ethics. A Code of Ethics for teachers is maintained and overseen by professional bodies that include the American Federation of Teachers, Canadian Teachers Federation, and the National Education Association. The Code of Ethics places expectations on teachers and governs the generalities of classroom management. Teachers cannot merely make up their own rules—we are obligated to abide by principles that provide a measure of professionalism for behavior toward students, peers, and parents. The following Code of Ethics (BC Teachers Federation, 2003) governs teachers in Canada:

1. *The teacher speaks and acts toward pupils with respect and dignity, and deals judiciously with them, always mindful of their individual rights and sensibilities.*
2. *The teacher respects the confidential nature of information concerning pupils and may give it only to authorized persons or agencies directly concerned with their welfare.*

3. *The teacher recognizes that a privileged relationship with pupils exists and refrains from exploiting that relationship for material, ideological or other advantage.*
4. *The teacher is willing to review with colleagues, students and their parents/guardians the quality of service rendered by the teachers and the practices employed in discharging professional duties.*
5. *The teacher directs any criticism of the teaching, performance, and related work of a colleague to that colleague, and only then, after informing the colleague of the intent to do so, may direct in confidence the criticism to appropriate officials who are in a position to offer advice and assistance. (See note below)*

NOTE: It shall not be considered a breach of Clause V of the Code of Ethics to report reasonable grounds for suspecting child abuse to proper authorities according to legal provisions and official protocol requirements. (BC Teachers Federation, 2003)

In addition to a Code of Ethics, guides to professional practice constitute the basics of teachers' responsibilities for the emotional, intellectual, physical and social development of the students entrusted to their care. This means that teachers assess educational needs, prescribe and implement instructional programs and evaluate the progress of individual students. Teachers must be mindful of their students' safety and rights to equality of opportunity, and must be considerate of their personal circumstances. Teachers are obligated to regard as confidential any information of a personal nature concerning students, and cannot divulge this information, other than to appropriate persons. Regardless of the temptation, teachers ought to speak constructively of students in the presence of students, teachers, officials, or other persons. These guidelines require that the teacher respect the uniqueness of each student's home, and share with the parent(s) (or guardians) information that will assist in the growth and development of the student. Teachers also must necessarily accept as a professional and individual responsibility the duty of reporting in an appropriate manner all matters harmful to the welfare of the school. Keep the Code of Ethics and these guidelines in mind as you develop policies and procedures for classroom management.

Managing Students and Facilities in Technology Studies

Technology studies offers the best conditions and the worst conditions for learning in the schools. The inheritance of infrastructure, laboratories, and workshops offers the potential for learning that is not anchored or tethered to desks and textbooks. This also produces conditions for accidents and attitudes that pit industrial philosophy against educational philosophy. There is the danger of mistaking an educational site for a worksite—a lab or workshop for a sweatshop. Technology teachers quite often slide down the slippery slope from classroom management to industrial management. Hence, their tolerance for unacceptable classroom behavior increases. What we would find on a jobsite is suddenly acceptable within a school site. Excuses proliferate: "A dirty cluttered lab or workshop is a sign that things are getting done." "This kind of language is what students will find in the real world so they better get used to it." "Safety systems break down everyday and you have to be quick on your feet to adjust." "They do it like this on the job." And so on—everything to deny the fact that education is a specific environment for fostering and modeling high ethical and behavioral standards. The question of what school labs and workshops are for, and the types of behaviors fostered and tolerated have been with audiovisual education and industrial education since its earliest days. For example, in the mid 1930s, a prominent educator in the U.S., wrote:

In industrial-arts shops, so much is heard about industrial processes and so little about education that it seems appropriate to raise the question, if perchance, industrial arts shops are primarily industrial plants and only secondarily educational institutions. It is one thing to cooperate with industry, but quite another to light educational lamps at its altars. (Ganders, 1934, p. 221)

In order to understand classroom management and facilities design, we have to address basic questions of purposes and ends. What are laboratories, studios, and workshops in the schools for? What should we tolerate? What are the consequences?

What are laboratories and workshops in the schools for? In the preface to this book, we clarified the mission of technology studies in the following statement: Providing experiences for young people to develop and question feelings, knowledge, and skills that empower them to participate in all facets of technological endeavor—from the practical to the political. This means that we demystify technology and its applications *as well as* resensitize students to the implications of their technological decisions and surroundings. This means that we establish a balance of the head, heart, hand, and feet in our lessons, activities, projects and courses. We strike a balance as we teach *about, through* and *for* technology. To meet this mission, we have to be diligent in the classroom tone we set, the behavioral and safety standards we establish, the activities and materials we use and the environment we design. Everything—what the students eventually know, do, and feel about our subject—is dependent on our diligence and vigilance in classroom management and facilities design. Technology teachers may have the most exciting activities, best teaching materials and the most current equipment, yet will fail miserably in their mission if they do not set a tone that is clean, welcoming and comfortable.

What should we tolerate? For their success, technology teachers have no alternative but to adopt and model the highest standards of behavior, ethics, equity, hygiene, and safety. We cannot tolerate the level of standards that we might find on a jobsite, in a factory, office, or studio outside of school. The world of work is different from the world of school. For example, while technology teachers might find acceptable levels of occupational safety standards on a construction site, there is a good chance that they will find low levels of gender and racial equity standards. While we might find high productivity standards in an animation lab, we will probably find low ergonomic standards. For technology studies in the schools, we cannot tolerate low standards in any category. We have to accept the fact that technology studies in the schools is about education, not training. Our mission is to educate students about, through and for technology and not to indoctrinate them in the narrow workings of a single industry.

Image and status are the consequences of what we accept as our mission and of what we tolerate. Tolerate foul language, inequities in participation, messiness in organization and a training mentality and your image will be appropriately disrespected. Accept indoctrination and the development of narrow tool skills as your mission and your status will be appropriately low. Through your image and status, you will be a minor player in the schools. Technology teachers can no longer afford to present themselves as minor players in the education of students. How you present yourself will determine your image and status in the schools. Your outlook and practices of classroom management will derive from your philosophy or your mission and what you want to accomplish and tolerate. Consider the following two true scenarios.

The philosophy for one secondary school that I have visited a number of times is oriented toward the humanities and performance arts. It is a magnet school for students who generally see themselves as expressive. The industrial technology program in the school is heavily oriented toward woodworking. The program has been reduced over the past six years from three technology teachers to one. Throughout this time, the technology teachers excessively complained about how unsupported they were. They ranted about the arts and humanities philosophy of the school and the lack of appreciation for the trades. The facilities were reduced at this time from two workshops and one lab to just one woodworking shop. It is among the drabbiest and messiest I have ever seen. The windows are painted over with battleship gray paint for a reason that I have yet to discern. When I asked why, the teacher answered that it was “done some time ago.” I have never seen a girl in the shop. As you can imagine, the classroom management of the teacher reflects the overall atmosphere of the program. It is a depressing place by any standards. The program is shrinking. What would you do if you were hired to teach in this school?

Another school where I often place student teachers promotes a comprehensive educational philosophy. Like the school previously described, the overall atmosphere is progressive. The technology program promotes an integration of information and industrial technologies. The facilities were redesigned to accommodate this philosophy. Two information and communications technology labs (i.e., digital media design, CAD) are separated by a general workshop. The two technology teachers schedule times to supervise students in the workshop. Both the labs and the workshops are clean, well lit, and organized. They consider their program to be central to the mission of the school and the students walk into their courses with high expectations. The upper level electives are extremely popular and the enrolment typically includes about 40% females. The environment is smartly decorated with numerous examples of student projects from the past. The classroom management system is consistent across the two technology teachers and is characterized by a strict, zero-tolerance atmosphere. Yet high independence and autonomous learning also characterize this atmosphere. The program is growing. What would you do if you were hired to teach in this school?

Setting the Tone

The first technology teaching position that I accepted resembled the first school previously described, but worse! This was 1984. It was in a rural district in central Pennsylvania. Dependent on logging and mining, the community was depressed with a 17% unemployment rate and all of the problems associated with hopelessness (e.g., high divorce rates, substance abuse, teen disillusionment). The secondary school (grades 10-12) had about 300 students. I was the third new technology teacher in as many years. The students had the notion that they would run me out of town just like the previous two technology teachers. The facility was a general workshop in horrible condition—literally a mess and a shame. There was not a working vise in the room. The wooden work benches were ball-peen hammered into a mess and had hundreds of nails driven into them. Most of the hand tools were broken and the power tools had severed cords or broken switches. The machines were out of alignment, dull and outright dangerous to use. Storage rooms were so cluttered that I could not walk. There was no chalkboard or bulletin board. No books. Other than the fact that it was in a school, there was nothing to suggest that it was an educational facility.

With an environment like this, you can imagine the behavior patterns of the students. Those who were enrolled in the technology course in the previous years wanted to go about their business and finish demolishing the place. The new students wondered what they were doing there. Intuition told me that nothing would change until the environment changed. I began working with a small group of interested students who helped out during the day, stayed after school and came in on a few Saturdays. We painted the walls, resurfaced the tables, repaired the tools and machines, constructed

Table 2. Parameters for setting the tone for acceptable classroom behavior (Petrina & Braundy, 1999)

A Student's natural tendency is to be fair and just!	***Two core assumptions***	**A teacher's natural tendency is to be fair and just!**

Parameters for setting the tone:

- ***Provide*** and maintain a ***clean***, ***inspiring*** classroom ***environment***
    - ***Architectural space.***
    - ***Infrastructure, furniture, tools, machines, and resources.***
    - ***Curriculum and information.***

- Set ***clear guidelines***, ***define boundaries*** and maintain ***clear expectations*** for acceptable classroom ***behavior*** and ***language***
    - Practice ***inclusive language*** without tripping over the words.
    - Discuss ***personal and social space*** and cultural differences that might apply.
    - Discuss ***interpersonal relations.***
    - Highlight ***respect*** for ***personal and school property.***
    - Discuss expectations for in-class ***tasks*** and ***work.***

- ***Model*** classroom ***guidelines*** and ***expectations***
    - ***Model respect*** and insist that students ***model respect.***
    - ***Model gender and racial equity.***
    - ***Model skills*** *without* reinforcing traditional gender roles.

- ***Consistently confront*** and address ***each act*** of offensive classroom behavior
    - Insist that ***students confront*** offensive behavior.
    - Doing ***nothing means*** one is ***complicit*** with offensive acts.
    - Use ***situation-based*** responses.
    - Stop ***humor that is stereotyped***, personal or is at the expense of a group of people (grouped by ability, class, ethnicity, gender, race, religion, sexuality).
    - ***Stop*** gender and racial ***slurs***, and swearing, in their tracks.

- ***Convene meetings*** (informal and formal) with parties to help resolve problems
    - Students Parents
    - Teachers Administrators

- ***Stay present***--Keep eyes and ears open and tuned-in to behavior and language

- *Show empathy* with feelings and words

- Read individual situations with an *eye toward prevention*

a chalkboard and frame, a bulletin board, bookshelf and a magazine rack. We built frames for new posters and placed them around the workshop. It took about two months to prepare the workshop for education. The students who were not helping just hung out during this time. I figured that as long as they were not destroying things or fighting, I was making progress. Eventually, they all got the message that I was on their side and trying to create a healthy environment. The process was bonding and nearly all of the sophomores I taught that year stayed with me for the next two years. For the second half of the year we built drafting boards for the instruments I ordered. I also bought two Macintosh computers and we began to do CAD. What saved me from failure was noting more than a can-do attitude and a no-nonsense, zero-tolerance tone of classroom management. A tone was set for education. A tone was set for what was acceptable and unacceptable.

Setting the tone is the single most important challenge a teacher will face during their first two years. The tone is set by your actions, commitment, disciplinary policies, and environment. Interesting activities and projects will follow, but initially have little to do with setting the tone for education. Setting the tone means that you take control of your classroom. You demonstrate leadership and model what you expect your students to do. If you want students to play by the rules, you have to play by the rules. And the rules ought to be primarily your rules—rules that promote achievement, equity, honesty, integrity and respect. The parameters provided in the box were established during my first two years of teaching and refined with a colleague.

Humor

In South Park's classic "Tweek vs. Craig" episode, the joke is on technology studies and home economics. This is either gut-splitting humor or low, despicable stereotyping, depending on your disposition. Everything that is right and everything that is wrong with humor is exposed in one twenty-minute episode. What is right is the reality of something laughable when a mirror is held up to reality—a scruffy, old shop teacher who grumbles and says not much more than "quit screwin' around;" a prissy home economics teacher who has perfected domesticity but is above it all; boys systematically reducing boards to scraps, girls attentively digesting tips for landing a husband, and a mixed-up kid who somehow copes in both shop and home ec. There is something accurate and hilarious in the caricature. What is wrong is the flagrant exploitation of stereotypes that have for three generations been unfairly foisted upon an entire group of caring, dedicated teachers. It borders on kicking someone when they are down. Enough already about shop and home economics! So much for the analysis humor—it takes most of the fun out of it. Now we feel guilty for laughing.

Humor studies researcher David Collinson (1988, 2002) distinguishes between functional and critical approaches to humor. Functionalist approaches follow prescriptions for reaping the benefits of humor but often result in situations that teachers manipulate with hopes of controlling the humor tap by turning it on and off. Critical approaches note that humor reflects alienation and disenchantment in students, and is a powerful form of resistance to authority. In this case, the joke may literally be on the teacher or classroom. Teachers who recognize that humor is often about power relations are inclined to overlook a fair amount of joking, expecting that this will diffuse unrest and create group coherence or unity. At times, teachers may have to suppress oppositional or subversive humor to maintain their authority or ethical boundaries.

There are numerous reasons to promote humor in the classroom: it is therapeutic, erodes barriers, encourages creativity, challenges worldviews, and motivates (Decker, 2004). Students up to about 8 years old enjoy physical comedy, clowning, exaggeration, literal humor, practical jokes and riddles. Students from 8 to about 13 years old appreciate a wider range of verbal humor, such as puns and word play, and increasingly turn to teasing in relationships. Older students tend to sharpen their teasing and appreciate verbal wit, sarcasm satire, irony, and parody (Shade, 1996, p. 111). Humor is age appropriate and, as Flowers (2001) cautions, should always be qualified by "judicious use" in education. As they manage behavior in general, teachers manage or mismanage humor. In many ways, the type of humor tolerated in a classroom directly reflects a teacher's policy on acceptable behavior and language. What is the role of humor in setting a tone for classroom management?

The optimal level of humor in setting a tone is a balance of teacher and student initiated wit. When the balance is tilted toward the teacher, he or she risks the charge of entertainer or inflated personality eager for attention. Doing the work of humor, he or she risks falling into the trap of the joke. When the balance tilts toward students, humor can quickly degenerate into cruelty and raise the question "who is in charge?" Finding an optimal level of wit is challenging, and teachers have to figure out how to let the students do the work of humor in the classroom. This may result in letting a class clown take the stage at times, but this strategy backfires in situations where you are forced to shut down the clown. The class may interpret this as a betrayal of trust. One key to establishing a balance is honoring the line between students and teachers. Avoid "reducing" yourself to the students' level of humor. Rather than eagerly trying to play a part in student culture, maintain your role in teacher culture. Otherwise, you risk *trying* to be funny rather than actually being funny. In *Being There*, Peter Sellers is funny for not doing anything to try to be funny. Difficult as it may be, the teacher's primary job is to model a tone for acceptable behavior, and monitor all actions and materials that tend to use individuals and groups as targets of humor. This means monitoring yourself, and even contradicting or transforming your core beliefs about humor.

Teachers are usually in safe territory with subject-specific humor. Art teachers draw on art-based humor, math teachers on math, and so on. Technology-specific humor has a history of drawing on a full range of genres, from slapstick to practical jokes to sarcasm and irony. Most technology teachers have executed technology-specific humor or were the brunt of it and can draw on these experiences to introduce a professional element of levity in the classroom. Technology-specific humor has a long history and one needs to merely consult popular magazines from the early 1900s to get a sense of this history. Browsing the Web turns up numerous technology and humor sites, where gems such as *CyberDork* are found among a large volume of juvenile or offensive humor. Comic strip author Scott Adams made his character *Dilbert* famous for bumbling office technologies and captured the gendered nature of this with the now-legendary declaration: "Technology—No Place for Wimps." Rich Tennant's *The 5th Wave*, published in *Computerworld*, and Randy Glasbergen's *Technology Bytes* are similar to *Dilbert*. R. Crumb popularized a genre of dystopian technology-specific humor in the 1960s and 1970s, and in the northwest, we have been treated to Ken Avidor's critical humor such as *Roadkill Bill*, published

Figure 1. Sexist humor (Source: Washington, 1976)

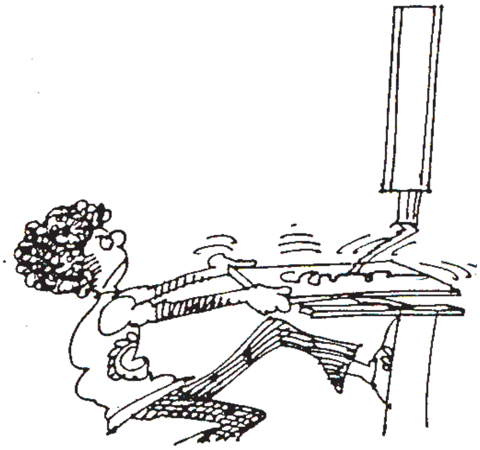
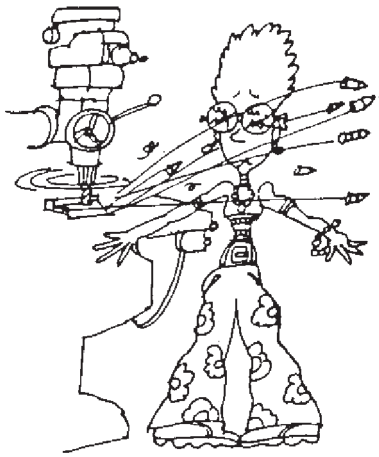


Figure 2. Sexist humor (Source: Washington, 1976)



by Car Busters. *Megatoons: Cartoonists Against Nuclear War* is a classic example of this dystopian genre from the mid 1980s. Leo Elshof's (2001) PhD research demonstrated that critical humor is effective in eliciting insights from students and teachers. Female cartoonists—Nitrozac's *The Joy of Tech*, Heather Vaughn's Tech High, and a number of women in *Dignifying Science*—tend to provide a reality aspect to technology-specific humor. Like any genre, this has a gender component to it and should be used with this in mind.

A good example of technology-specific humor at the expense of a group of people is in *Washington State Industrial Arts Safety Guide*, the popular industrial education guide from the mid 1970s (M&M Protection Consultants, 1976). Although the enrollment of girls in industrial education was only about 6% in 1976, 75% of the 32 cartoons in the guide depicted girls and women looking foolish or doing reckless things around machines (Figures 1, 2). The two reprinted here are among the mildest. Done in the thick of the women's liberation movement, the cartoons were backlash. The sad conclusion is that there are still teachers today who photocopy and distribute the handouts from the guide, complete with the cartoons on the same page as the safety rules. Many thousands of girls and boys were exposed to this insensitive humor over the past thirty years. What are the messages?

Gender, Sexuality, and Diversity

Under no circumstances should harassment or discrimination based on ability, age, class, gender, race, religion or sexuality be used or accepted within any educational context. This also holds true outside of schools. Yet, through personal accounts and research, we know that neither schools nor workplaces are free from harassment and discrimination. Prejudice such as racism and sexism can be overt or covert, specific or structural. In many institutions, optics, or the management of appearances, work to control what is seen. On the surface, appearances suggest acceptance and fairness, but just below the surface are conditions that work against full participation or dignity. Conditions such as a privileging of certain norms of behavior and loyalties, exclusion from spheres of influence, good 'ol boy networks, tacit quid pro quos, and the favoritism or preferential treatment resulting from these conditions account for a fair amount of systemic prejudice, racism and sexism. Hence, equity is complex and can be elusive even under the most innocent-looking conditions. Vigilance is the operative word.

Equity typically refers to qualitative concerns for fairness and justice. To address equity, we may have to demand *unequal* treatment (equal treatment is *not* always the answer). Some groups (i.e., girls in technology) may require differential treatment to have a fair chance to participate and perform. Equal outcomes may require differential treatment. *Equality* normally refers to quantity and concerns with parity across groups on some index for measurement (e.g., access to technology, pay scales). We have to attend to barriers as well as intervene in *status quo* conditions to achieve equity and equality in technology studies. We may have to make special measures for reasonable accommodation of differences. In the U.S., Title IX of the Education Amendments was passed in 1972 to prohibit sex discrimination in all aspects of federally funded education programs, including technology studies. However, as noted in Chapter VII, girls in the U.S. and Canada continue to be relegated to traditionally female programs, which ultimately impacts their earning power and job prospects. The existing state of equity forced the National Women's Law Center (2002) to conclude that "biased counseling, the provision of incomplete information to students on the consequences of their career training choices, sexual harassment of girls who enroll in non-traditional classes, and other forms of discrimination conspire today to create" a system "characterized by pervasive sex segregation" (p. 3).

What are some reasons that students may be different from each other? What differences are moderated by gender and sex? Difference should *not* suggest failure, helplessness or inability, but it is often constructed this way. Students are different for any number of reasons. Differences in confidence around certain technologies, and in turn capability, are especially moderated by gender. These differences are not derived from essences of the sexes. In other words, confidence with industrial or information technologies and resultant aptitudes are not determined by one's biological sex. The issue is rarely, if ever, technophobia per se. A large majority of girls and women across the world demonstrate high levels of comfort and skill with domestic or office technologies. Others excel in technical trades and high tech careers. Instead, these differences are dependent on sociocultural factors such as bias, overt discrimination, differential treatment, isolation, socialization, and stereotyping. A student's upbringing and socialization play extremely powerful roles in forming her or his abilities and confidence. "Early childhood socialization," according to Ehrhart and Sandler (1987):

reinforced not only by parents and teachers, but also by the media—teaches children roles, attitudes and behaviors thought to be 'appropriate' for each sex. In general, boys are encouraged to be active and independent, to explore and to learn how things work. Girls are 'taught' to be passive, verbally oriented, and dependent. Boys receive chemistry sets, building toys, trucks and sports equipment; girls receive dolls, kitchen equipment, and sewing and embroidery kits. Parents' expectations that their children's interests and achievements will follow traditional sex roles will steer girls away from certain areas; in contrast, encouragement from parents to succeed in math, science, and technology is crucial in a girl's decision to take these courses in high school. (p. 3)

Psychologist Leonard Sax (2005) argues differences in socialization are manifested in neurological and physiological differences between the sexes. Hence, differences become "hard-wired" over time and are not so easily overcome. Sax uses this as a justification for single-sex courses in certain subjects, such as math, science and technology.

Stereotypes more or less derive from gender norms and sex roles. Once students reach school age and adolescence, gender stereotypes are fairly well established (de Castell & Bryson, 1998). We generally stereotype boys by what is deemed appropriate or considered masculine attributes and girls by feminine attributes or traits. Portrayals of adults reinforce stereotypes for students. Men are stereotyped as work-oriented and portrayed as breadwinners; women are stereotyped as relationship-oriented and portrayed as familial caretakers. Powerful peer pressures work to maintain gender norms and stereotypes. A psychological and social toll is exerted on students who do not fit into the gender roles. Emotionally coping with isolation or labels of deviance is incredibly demanding. Expectations are changing and it is becoming more acceptable to see students contradict norms but gender works in subtle ways. Researchers report that it remains more difficult for boys than girls to contradict traditional gender norms. Messages students receive are mixed. On one hand, stereotyping in school is common; on the other hand students are told that they can act out and pursue the life-style that they want. Boys and girls see their female role models juggling work outside the home with domestic responsibilities. Schools combine equal opportunity and "just do it" messages with stereotyped course enrollments and biased treatment by counselors and teachers. What are you willing to do about this as a teacher?

Biases are hidden and subtle as well as obvious. Sex-biased or sexist curriculum materials (e.g., books, clothes, equipment, posters, software, tools, videos, Web sites) in technology tend to give girls the message that they are not important or portray them in roles of helplessness or mindless decoration. History materials in technology courses tend to emphasize inventions and innovations made by men, and in most cases, white men. Contemporary examples refer to men and male-dominated industries or technologies. Projects in these courses by and large appeal to a traditional form of masculinity and disregard the interests of most girls and a number of boys. Isolation or conformity is usually the only option. As mentioned in Chapters I and VII, language that is not consciously gender-specific tends to default to the male in technology courses. Active bias is often much easier to challenge than more subtle forms. The target is clear and intervention can be rapid and specific. Equity requires a commitment to intervene through classroom management and all forms of educational influence and practice.

Equal opportunity and equity interventions are ranked on a scale from equal access, equal treatment and equal outcome to systemic reform. Equal access means that administrators, policy makers and teachers have removed obvious barriers to full participation in education (e.g., courses, sports). The doors are open for all courses. Equal treatment means that all students are treated the same—teachers withhold preferential treatment and maintain a climate of equality. Boys and girls receive the same treatment. Equal outcome means that special accommodations are made and treatment is differentiated to achieve equal results. You may spend more time with certain students in your class to "bring them up to speed" to perform at equal levels with their peers. You "give them a fair chance," so to speak. You may also make adjustments to projects to incorporate the interests of girls or a multicultural perspective. Equal outcome interventions often receive accusations of reverse discrimination. What are the shortcomings of these levels of interventions? How do they work together? How common are they? Systemic reforms aim for the roots of inequities and the causes of overt or covert bias and discrimination. Systemic reform challenges the "additive" mentality that characterizes surficial or superficial reform. Instead of adding a few items or projects that may have s gender-specific purpose or multicultural theme to an existing course or curriculum, systemic reform means that we address the biases, discrimination and stereotypes already built into the course or curriculum. Systemic reform typically means that teachers address their personal positions on gender and work through issues that mitigate an expansion of masculinities and a pro-feminist outlook.

Researchers of feminisms and masculinities are finding that people are not unidimensionally or uniformly gendered (Braundy, 2004; Connell, 2002). Remember, gender should *not* be reduced to biological sex. Feminism, generally associated with the rights of girls and women, is best understood as the plural *feminisms*. Masculinity, mainly associated with the expression of power by boys and men is similarly best understood as the plural *masculinities*. A key finding is that individuals and biological sex groups demonstrate a range of gendered positions within a continuum inasmuch as they demonstrate a range of political positions on a continuum (Figure 3). Positions are dependent on circumstances and issues. Theorist of gender Judith Butler argues that gender is something we perform—points on the continuum are intentional and not determined by biological sex. Few people are polarized on the continuum, and most perform or demonstrate combinations of traits. While educators have found gender role reversal to be an effective method for altering students' perspectives, the central point for classroom management is that teachers must anticipate and accommodate students on any and all points of the continuum. Effective classroom management in technology studies requires that we necessarily accept or celebrate a full range of expressions of gender and sexuality. Doing technology—being a(n) engineer, technician, trades worker or technologist—is not limited to one or two points on the continuum. A technology environment and classroom management style that encourage a single, narrowly defined masculinity

Figure 3. Gender and sexuality

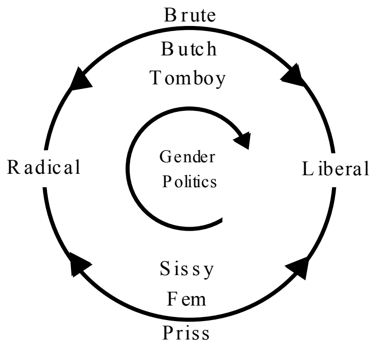
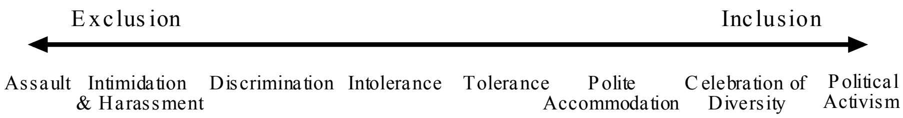


Figure 4. Diversity Continuum (Vancouver School Board, 2004)



violate equal access conditions.

Equity is a question of diversity. About 96.5% of all students take at least one technology studies course in grades 8-12, which is due to requirements in grades 8 or 9 in North America. About 61.5% (Females 58%, Males 65%) take three or more technology courses, which include business and information technology. In the U.S., African American, American Indian and Hispanic students take more technology courses on average than white students. Asian Americans take one technology course less on average than other students (Tabs, 2003, p. 44, 64, 122, 150). This is consistent in Canada, where Asian students are up to three times more likely to transition directly to a university. Students in technology studies are diverse, perhaps more diverse than we acknowledge or accommodate with curriculum materials or classroom management styles (Rider, 1998). And the question of diversity is one of inclusion versus exclusion (Figure 4). As William Chase (1994) put it in "The Language of Action," "Diversity… is not polite accommodation. Instead, diversity is, in action, the sometimes painful awareness that other people, other races, other voices, other habits of mind, have as much integrity of being, as much claim on the world as you do. And I urge you, amid all the differences present to the eye and mind, to reach out to create the bond that will protect us all. We are meant to be here together." (p. 2).

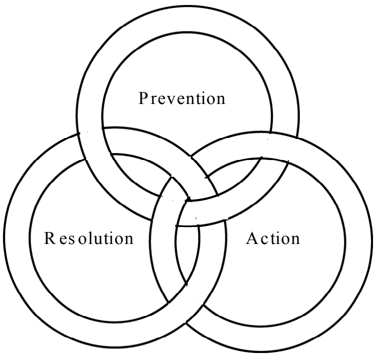
Discipline with Dignity

Example 1. Sketchy management (Source: Budnikas, 1998)

Mr. Humphry gave a demonstration on dimensioning and assigned an exercise to be handed in at the end of class. Peter's drawing of a dimensioned object was completed long before most students had their paper taped to the table. He pushed his books aside and began to draw a building. Fifteen minutes later, he completed a detailed sketch of a cottage. Mr. Humphry approached Peter and the following ensued. Mr. Humphry: "How many times have I told you not to waste time drawing this crap on good paper?" Peter: "But I completed my assignment." Mr. Humphry: "No you haven't. You didn't put your name on it. You aren't going to lunch until your name is on it. And erase that." Peter began erasing and didn't stop until he wore a hole through the paper. He crumpled it up, threw it in the trashcan, and sat there staring at the assignment through the lunch period.

In this incident, how would you have reacted as the teacher—or as the student? There was obviously a trend to Peter's behavior and to Mr. Humphry's reactions. Mr. Humphry used behavior modification to discipline Peter but the results were mixed. More than likely, Peter will resent Mr. Humphry even though he may reform his behavior in class. If the consequence is the opposite—Peter increases his tactic of drawing in class—then Mr. Humphry has issued a reinforcement rather than a punishment. In behavior modification, the consequence of the discipline following a behavior determines whether a reinforcement or punishment has been given. Behavior modification, which consists of positive and negative reinforcement and punishments, works with some students better than others. It still has its place in education although theorists question the efficacy and ethics of certain rewards and punishments. An exhaustive study of behavioral modification in the schools during the late 1970s led Rutter, Maughan, Mortimore, Ousten, & Smith (1979) to conclude

Figure 5. Discipline with dignity (Mendler & Curwin, 1983)



that high levels of corporal punishment led to worse student behavior.

Discipline with dignity originated during the 1970s. Now trademarked and successful, Discipline with Dignity™ offers teachers a sound alternative and complement to behavior modification techniques. Curwin and Mendler (1988, 1999) refer to discipline with dignity as "three dimensional discipline" (Figure 5):

- **Prevention:** What can be done to prevent problems?
- **Action:** What can be done when misbehavior occurs to solve the problem without making it worse?
- **Resolution:** What can be done for the out-of-control student?

The premise of these three dimensions is straightforward: *prevent* discipline problems from occurring, *solve* problems when they do occur and *resolve* difficult and out of control behavior. Technology teachers find these three dimensions to be essential to safety as well as classroom management. Discipline with dignity means that values such as open communication, mutual respect (dignity) and commitment to common goals are backed up with classroom management techniques for prevention, action, and resolution. Remembering simple techniques, such as proximity, eye contact and privacy (PEP), for discipline translates into discipline with dignity. Curwin and Mendler (1999) recommend these guidelines:

1. The most practical discipline technique is to welcome every student.
2. It takes less time at the end when you spend more time in the beginning.
3. When students withdraw, make an even bigger invitation.
4. Discipline responses require a two-stage approach: stabilize and teach.
5. Model effective expressions of anger with your students.

Most schools have fairly standard discipline rules and procedures for dealing with students: Breaking rule X begets punishment Y. One purpose is to minimize referrals to the administrative office; the implication is that teachers must resolve many problems within the classroom. Only major offenses, such as foul language directed at a teacher, aggressive bullying, theft and vandalism, possession of illegal substances or a weapon, or intoxication, require direct referral to administration. The bulk of incivilities have to be resolved in the classroom, where power struggles test even the most experienced teachers. Here, interactions are not so easily reduced to a simple equation where infringement X = punishment Y. Adept at avoiding power struggles, effective teachers individualize discipline, work with clear classroom rules and procedures, monitor compliance with the rules, deal with consequences quickly and consistently, insist on student responsibility and accountability for behavior,

Table 3. Seven principles for discipline with dignity (Source: Mendler, 1993, p. 1-4)

1. **Long-term behavior changes vs. short-term quick fixes.** People take time! Dealing with discipline takes time.
2. **Stop doing ineffective things.** With regard to discipline, some kids simply do not respond to "common sense" or "empirically sound" strategies.
3. **I will be fair, and I won't always treat everyone the same.** Some who read the preceding scenario will be concerned about the disciplinary message to other kids.
4. **Rules must make sense.** Rules viewed as stupid are least likely to be followed. Rules in schools should be the guidelines needed for success to happen.
5. **Model what you expect.** Let students see you living by the same code of behavior you expect.
6. **Responsibility is more important than obedience.** Obedience means, "Do not question and certainly do not be different." Responsibility means: Make the best decision you possibly can with the information you have available.
7. **Always treat students with dignity.** This is perhaps the most important of all the principles, because without dignity, students learn to hate school and learning.

and clearly communicate information. In many ways, the intent is to off-load the responsibility for discipline to students, through self-discipline and self-control. Humanists tend to advocate permissive, laissez-faire techniques, believing that autonomy is instilled through maximum freedom. On the other extreme, militant disciplinarians advocate law and order, believing that strict comportment leads to responsibility. Some argue that the result of these approaches is spoiled brats or helpless conformists. Discipline with dignity means finding a middle ground. Discipline with dignity provides a framework to scaffold rules and procedures:

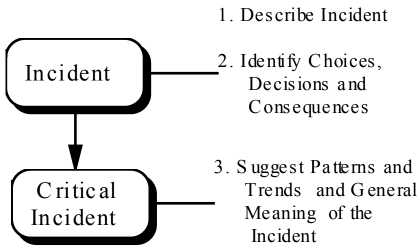
Example 2. Angela's embarrassment (Schneider, 2000)

When quiet was restored the lesson continued, but so did Angela's conversation. Mr. Davis spoke directly to her in a calm but stern voice: "Angela, if you wish to sit with your friends you'll have be quiet. If you're not, I'll ask you to return to your usual seat." Looking innocent but visibly embarrassed, Angela nodded in agreement. Again the lesson continued and, after a brief respite, so did the talking. Mr. Davis again addressed Angela directly and again with a calm, stern voice: "OK Angela, I need you to go back to your usual seat so I can finish the lesson." "No, no, please?" Angela pleaded, now red in the face. "Quickly now," said Mr. Davis. And when she took her old seat, "Thank you Angela." The lesson continued without much interruption but the classroom tone had changed.

Critical Incidents of Behavior

In the previous incident, Angela faces two clear courses of action: be quiet or be moved to a new seat. With the warnings unheeded, Mr. Davis is forced to follow

Figure 6. Critical incident method (Source: Tripp, 1993, p. 26)



through with action. A critical incident is a situation or event that marks a significant turning point in the behavior of a student, or a commonplace situation where a student has at least two clear courses of action to take. These incidents are critical when they are indicative of motives, patterns, and trends. Critical incidents do not have to be dramatic or obvious and for the most part, are routine until rendered critical by the teacher through description. It is a technology teacher's responsibility to monitor her or his lab or workshop for incivilities but critical incidents remind us to be observant of all forms of behavior. A critical incident can be a situation or event that reflects a turn in behavior that is either negative or positive. Like discipline with dignity, the critical incident approach is a method for maintaining an effective program of classroom management (Tripp, 1993). The critical incident method trains teachers to recognize and connect the behavioral choices students face, the decisions they make, the consequence that occur and underlying behavioral motives, patterns and trends. This method helps teachers record situations "as observed" and analyze the situations for motives, patterns and trends. It helps teachers document situations from within and move outside situations to analyze.

Ideally, teachers will not incur any classroom incivilities and will merely focus on C&I. Realistically, this will never happen. Behavioral and emotional problems will always occur and the task of classroom management is to minimize their frequency and limit their consequences. Basically, the critical incident method involves six steps (Tripp, 1993) (Figure 6). First, train your senses to observation. This requires that you recognize details within larger contexts. Second, focus on behavioral or intercommunication situations of your students in addition to their skills-based activities. Remember, even commonplace situations can be rendered into critical incidents if you notice turning points, patterns, or trends. Fourth, provide an accurate and detailed account of the incident. Try to pinpoint "what happened" without embellishing. Fifth, describe the choices the students(s) faced, decisions made and the consequences incurred. These consequences may be negative or positive. Sixth, render this incident critical by describing the patterns or trends that are in play. By focusing on critical incidents you will be able to document and monitor the progress of your students' behavior and social interactions. This will be invaluable in maintaining and reforming your classroom management style and techniques. The critical incident method is not to be used to create a dossier for each student. Rather, this method helps teachers view classroom management from the students' perspective as a series of choices, decisions and consequences. It is the teacher's task to generate and administer consistent modes of punishment and rewards that correspond to consequences or incivilities.

Classroom Incivilities

Classroom incivilities encompass teacher initiated and student initiated disruptions to acceptable, civil, orderly classroom conduct. The value of exploring and addressing classroom incivilities is that we are reminded that teachers are not innocent in the causes of classroom problems. Simply put, classroom incivilities refer to disruptions born out of disrespect and irresponsibility (Boice, 1996). Examples include incidents where a teacher is unprepared, insensitive to ethical expectations or an equitable climate, disinterested in their subject, or disrespectful toward specific student rights. Examples include incidents where a student is intentionally indifferent, arrives late or walks out, without prior agreements, distracts with unrelated tasks (e.g., computer browsing, text messaging), delivers loud, sarcastic gestures, remarks and insults or carries on a conversation at the expense of others. Classroom incivilities may be indiscrete disruptions that affect the cohesion or progress of the group or relatively discrete distractions that affect a smaller pool of individuals.

Classroom incivilities are culturally specific in that expectations and tolerance for disruptions differ from culture to culture. In North American classrooms, incivilities are common for whatever reasons. Some cranky commentators blame the students and their upbringing—"the young, by the time they are ready to enter college, have established within themselves a mental fixity born of fear and disorientation that is strikingly narcissistic in its monadic self-encapsulation, in its fear and resentment of authority, and in its conformist rigidity and intellectual lassitude. The result is the high-tech barbarian" (Bartlett, 1993, p. 308). A certain level of disrespect and irresponsibility seems normal and the question is how much a teacher (or a student) is willing to tolerate? Classroom incivilities take their toll, resulting in a large turn-over of new teachers, leaves of absence for veteran teachers and disillusionment in students. High levels of incivilities are embarrassing for teachers and coping mechanisms kick in to create reactions that seem rational. Some teachers ignore a large volume of incivilities or become retaliatory or aloof, creating other incivilities in turn. They may shift from the use of prosocial motivators ("Do you understand what I'm saying?' or "You can do better than this") to antisocial motivators (threats and guilt induction). Some resort to winning students over by pandering or thinking that entertainment is a necessary replacement to education. Teachers risk being taken for deserving targets without the tools to address incivilities.

Example 3. Blaming Albert

> Albert quickly tired of the CAD demo and started fidgeting with small scraps of cardboard on the table. Fidgeting alone was not satisfying for long and he began to throw the small scraps in Joyce's direction every time Ms. Roberts was busy looking elsewhere. If the opportunity was good, Albert threw a piece in other directions. Twenty-five minutes into the demonstration, Ms. Roberts needed something that she didn't have at her workstation and got up to get it. The flying scraps got worse. "Cut it out," Ms. Roberts cautioned to Albert. Albert smiled, threw another piece and said, "cut what out?" Stop throwing the cardboard, Albert. "What are you talking about? I never threw anything."

How should Ms. Roberts deal with Albert? What is the problem? As indicated, some of the best techniques for classroom management include clear parameters that set the tone for acceptable behavior, discipline with dignity and a critical incident approach to documenting and analyzing incivilities. Correctives and preventives for many incivilities involve little more than these basic techniques, which draw on accessibility, empathy, friendliness, and responsibility. Researchers find that students' misbehavior and resistance often depend on how they interpret the teacher. Teachers who appear disorganized, distracted, irresponsible, uncaring, or overly casual will see similar behavior in their students. Giving off these types of cues will almost invariably escalate toward chronic incivilities. Prosocial motivators that preserve dignity for all parties are key tools for reducing incivilities. Incivilities drop off dramatically with prosocial skills, such as verbal and nonverbal signals of care and warmth. A majority of students often blame teachers who allow classroom problems to go unchecked (undisciplined or without dignity) for incivilities that occur in the classroom. In labs and workshops, unchecked incivilities can be disastrous and result in a damaged infrastructure or injury. Certain forms of incivilities—aggressive and exploitive behavior, homophobic intimidation, racism, and sexism—must be stopped in their tracks. There is often a thin line between incivilities or disruptions and bullying or hazing.

Violence, Bullying, and Hazing

Violent behavior among adolescents and teens in North America has been increasing over the past two decades, but in the 1990s the teen homicide rate decreased by

33%. Although well publicized, school-based homicides or life-threatening assaults are rare. Violence in schools is likely to be in the form of fights and bullying. The concept of "bullying" tends to trivialize the realities of school violence while exaggerating the influence of the bully. The Columbine High School tragedies demonstrated quite clearly that it is not always bullies who are dangerous. The bullies are merely overt with their violence, taking pride in their capabilities to influence and intimidate their peers. In effect, bullying compensates for underlying behavioral or emotional disturbances and imbalances. It is anti-social but nonetheless common. Violent behavior in school is much more prevalent than commonly perceived when violence is redefined to encompass bullying and hazing. Bullying is defined as the convergence of a power differential between two or more students, the intention to exploit this power differential with intimidating and obnoxious behavior, and the opportunity to exploit the differential over and over. Technically then, there must be a power differential, intentionality and repetition to define behavior as bullying. There are physical and verbal bullies as well as bully-victims who feel forced to retaliate with bullying behavior. Research suggests that about 10% of students in any school exhibit bully behavior and about 5% are bully-victims who retaliate but not necessarily against their bullies. In other words, bullying creates increasingly larger circles of bullies and victims (Elias & Zinns, 2003; Vaillencourt, Hymel, & McDougall, 2003).

Nearly one third of K-12 students report that they experience bullying, either as a victim or as a perpetrator, according to a survey of 15,686 public and private school students in the U.S. (Nansel et al., 2001). More than 16% said they had been bullied occasionally during 2000 and 8% reported bullying or being bullied at least once weekly. Of the 30% who reported being involved in bullying, 13% reported that they had bullied, while just over 10% said that they were victims. Approximately 6% of the students reported that they had, at different times, been bully and victim (bully-victims). Frequencies suggest that bullying is most prevalent among grade 6-8 students and slows down in grades 9-10. About half of all boys surveyed said it was ok to hit someone who made them angry while one in five girls felt the same. About 11% of boys were bullied once a week while 6% of girls were involved in bullying at least once per week. For boys, bullying normally takes the form of threats, physical harm, and name-calling. For girls, bullying normally involves name-calling, teasing, rejection, and the swiping of personal belongings. Bullying is also linked to technology, where emails, hate Web sites, blogs and instant messages convey forms of aggression that are emotionally damaging. Students report that bullying and violence generally goes unreported and happens with few consequences at school.

Bullying and hazing have emotional and physical consequences, and about 75% of students involved report injuries, academic problems, fights with parents, retaliation toward others, eating and sleeping problems, anger, confusion, embarrassment and guilt. Hazing is a form of ritualistic bullying—"acceptable intimidation"—and is most prevalent among high school students. About 48% of students who belong to a clique or gang are subjected to hazing activities, and about 43% are subjected to humiliating activities. Both female and male students are subjected to hazing but males are at the highest risk of dangerous hazing. Hazing is not limited to at-risk students and even groups typically considered safe, such as church groups, haze new members. Students who are bullied or hazed report loneliness and difficulty making friends, while bullies are more likely to have poor academic performance, smoke and drink alcohol. However, how students perform in school and the peers they hang out with are the best predictors of whether they drink alcohol, smoke cigarettes, or carry weapons. The National Longitudinal Study of Adolescent Health in the U.S. contradicts the common view that race and socioeconomic level are the predominant predictors. Regardless of their race or sex, students who said they had "frequent problems with their schoolwork" were more likely to use alcohol, smoke cigarettes, become violent, carry weapons, and attempt suicide. The numbers are extremely high—25% of grades 7-12 students carried some form of weapon to school during 1999 and 10% drank on a weekly basis—but school performance is the best predictor of whether a student becomes involved with drugs or violence. Poverty, nevertheless, remains the driving force behind at-risk students and learning disabilities.

At-Risk and Special Needs Students

"At-risk" and "special needs" are contemporary concepts to recognize that some students require specific instructional and classroom management strategies tuned to their unique circumstances. At-risk refers to any student who encounters major obstacles to the successful completion of school or who is prone to developing a disabling condition. The causes may be biological or socioeconomic, with signs such as alienation or alcohol and drug abuse. These students tend to be perennially on the verge of dropping out. Other students are at-risk of committing an offensive act or recidivism. Students who are at-risk typically have a range of special needs and not the least of is their need for respect and success. Technology studies has a long history of dealing with at-risk students and most technology teachers often tell stories of their "problem" students who progress from at-risk to on-time and motivated. These teachers proudly note that the worst students in the school are sometimes their best students. Historically, a majority of administrators and counselors viewed laboratories and workshops as "dumping grounds" and last resorts for at-risk students. Perhaps mistakenly, some technology teachers internalized this, interpreted the principle role of their facility to be occupational therapy and isolated their subject from the majority of the school. Such is the legacy. Placing five or six at-risk students in a single technology course, with expensive, dangerous equipment made for a volatile mix. This practice submitted technology teachers to significant and often impossible challenges to manage these students and the others in the facilities. The safety net for at-risk students was more likely to be a sympathetic teacher than the content or equipment of the curriculum. The key is to *identify* with students, whether at-risk or not. But a connection with students does *not* mean that teachers are reduced to the students' friends. Students need caring role models, not more friends.

In the U.S., the dropout rate is 12-18% and in Canada the rate is a bit higher (e.g., BC dropout rate is 20%). In the U.S., as many as 380,000 students drop out of grades 10-12 each year, but dropout rates correlate with race and socioeconomic status. For example, 8-17% of white students, 14-26% of black students, and 30-46% of Hispanic students drop out. The percentages increase if the students are foreign born and immigrated to Canada and the U.S. In Canada, 45% of all First Nations (North American Indian) students drop out. In large urban school districts, where a majority of students are from poor families, dropout rates are 25% and in one out of four of these districts the dropout rates are 35%. The poorest of the poor districts have dropout rates that exceed 45%. Sadly, the lack of a high school diploma correlates tightly with unemployment and incarceration rates. In Canada and the U.S., where incarceration rates are the highest in the world, 68% of all prison inmates are high school dropouts. Dropouts are likely to be unemployed, exposed to violent crime and convicted of criminal behavior before they reach 21 years of age. There are high correlations between dropout rates and poverty, and again between dropout rates and behavioral or emotional problems.

At-risk students are not special needs students per se. About 10% of the overall school population is diagnosed with some special need (mild or severe), and percentages range toward 30% depending on geographic region or socioeconomic and racial status. Educational systems in Canada and the U.S. have enabling legislation to ensure that all students have a universal access to public education. In the U.S., the *Individuals with Disabilities Education Act* (1975) protects all students who have special needs. In Canada, provincial laws range from mandatory to permissive provisions for access. Equity legislation tilts the tables toward dignity of risk for students, allowing for inclusion or integration in "mainstream" classes rather than exclusion of segregation in special education classes and extracurricular activities. Students with special needs are required to be accompanied by an Individualized Education Plan (IEP) that guarantees a specifically tailored program to meet the special needs of students who have disabilities. The IEP is a contract developed by administrators, disability specialists, teachers along with the student and her or his parent(s) or guardian. IEPs may or may not include a plan for work in technology studies and it is the technology teacher's responsibility to see that their subject is included in the IEP.

Due to family circumstances and poverty—disabling conditions—at-risk students often have special needs that derive from one or another behavioral, emotional or

Table 3. Indicators of behavioral or emotional difficulty or disorder (Adapted from Disability Resource Centre, 1997)

Behavioral indicators	Social indicators
• Low self-concept. • Troubled relations with peers. • Inappropriate relationships with teachers, parents or other authority figures. • Deficits in speech and language. • Difficulties in auditory and visual perception. • Poor quantitative and computational skills. • Deficits in basic motor skills. • Other signs of social-emotional problems • .	• Poor social perception. • Lack of judgment. • Lack of sensitivity to others. • Difficulty making friends. • Problems establishing family relationships. • Social problems in school. • Social disabilities of adolescents and adults.

developmental difficulty, disturbance, disorder or disability. Behavioral problems frequently occur with emotional problems such as depression and anxiety. From behavioral or emotional disturbances, students may develop intellectual and learning disabilities, language difficulties, or an attention deficit hyperactivity disorder (ADHD). Students in poverty are more likely to develop difficulties or depressive symptoms and internalize disorders. Other special needs include hearing and visual impairments, or special gifts and talents. Some students attend school with chronic health impairments, autism, or with general learning difficulties that are not considered special needs. Although there is a range of indicators of behavioral and emotional difficulties (Table 3), teachers should not immediately conclude that a particular student is "disabled." The act of labeling students generates a host of social problems for the particular student.

Difficulties, disturbances, disorders, or disabilities may be transitory rather than permanent. Researchers caution that diagnoses or judgments of disability ought to be reserved for students who exhibit these indicators over a long period, to marked degrees and when educational performance is adversely affected. *Severe* behavioral disabilities mean that the student demonstrates these three qualifications and one or more of the following:

- An inability to learn, which cannot be explained by intellectual, sensory or health factors, or
- An inability to build or maintain satisfactory interpersonal relationships with peers and teachers,

Table 4. Guidelines for accommodating cognitive or intellectual disabilities (Adapted from BC MOE, 2000, p. 21)

Language and text organization	General
• Avoid complex sentences. • Use simplified vocabulary; avoid dialect or idioms. • Express concepts at a literal level. • Provide clear, simple instructions that can be broken down into component steps. • Highlight important information for easy recognition. • Provide advance organizers, definitions of key vocabulary with illustrations. Visuals • Include illustrative material (pictures, graphs, etc.) That supports text.	• Provide multi-sensory instruction. • Avoid unnecessary complexity in activities. • Provide opportunities for approaching concepts at various levels of complexity. • Illustrate concepts by real-life examples connected to students' experiences. • Include explicit aids for remembering and procedural instructions. • Offer group work and paired peer activities. • Provide summaries of important information. • Be appropriate to age level, even if adapted in language, conceptual complexity, and structure to meet intellectual ability.

or

- Inappropriate types of behavior or feelings under normal circumstances,

or

- A general pervasive mood of unhappiness or depression, or
- A tendency to develop physical symptoms or fears associated with personal or school problems.

Of course, disabilities vary from pervasive disorders (autism, schizophrenia) to physical conditions (blindness, hearing impairment) to intellectual disabilities. Students with intellectual disabilities function significantly below the norm for students the same age. Indicators include significant deficits in language and concept development, a concrete learning style and difficulty with abstractions, the need for direct instruction with frequent review, difficulties in generalizing, problems with focusing on what is important, and difficulties with independent learning. Use the following guidelines to facilitate instruction for students with cognitive or intellectual disabilities (Table 4) (BC MOE, 2000, p. 21):

In addition to students with intellectual or cognitive disabilities, some students have a range of physical difficulties with vision including blindness, partial sight, or low *vision. Others have hearing impairments and may be hard of hearing or deaf. Some have mobility impairments that are neurological or orthopedic. Still others have learning disabilities.*

Learning Disabilities

A learning disability is defined as a deficit in ability to process information. Students with learning disabilities have normal cognitive potential with disorders in their learning: significant difficulties in perception and the acquisition and use of listening, speaking, reading, writing, reasoning, and mathematical abilities. These difficulties often impact memory, problem-solving abilities, and attention span. Students with learning disabilities may have trouble processing, generalizing, or expressing their ideas in writing even when they understand the content. Learning disabilities are *not* behavioral or emotional problems. Learning disabled students who otherwise have no emotional impairments have difficulty integrating or producing information. Some students have difficulty reading and following printed directions—key safety requirements in technology studies—but respond to oral directions. Some students struggle with calculations, also key to technical work, but respond when given extra time and an environment free of external pressures. Some students have trouble writing and cannot produce written materials under strict time constraints. These types of difficulties may manifest themselves as behavioral or developmental problems (dyslexics are overrepresented in prison populations), but these problems should not be conflated with learning disabilities. For the most part, learning disabilities are detected rather late, most often identified between the ages of 11 and 17. Learning disabilities are common, with about 3 million students in the U.S. diagnosed and in special education classes (Disability Resource Centre, 1997).

Dyslexia, dysgraphia and dyscalculia, are the most common learning disabilities. When students with dyslexia look at a page or screen of text, they see the letters. They can tell someone the letter's names. But is takes time for them to articulate the words that the letters form. Some dyslexic students can easily decipher longer words such as *electricity* but trip over shorter words like *four* or *year*. Dyslexia affects about 20% of all students, boys and girls alike (Gorman, 2003). Understandably, dyslexia usually accompanies dysgraphia, or the ability to write. Assistive technologies for both include audio and videotapes of instructional materials, and voice recognition software. Accommodation also means that teachers provide reading and written materials well in advance of deadlines, the use of highlighting to emphasize important points, sequential organization of material and control of distractions. Dyscalculia refers to difficulties in recognizing order in numbers, an extremely important skill for mathematics. Assistive technologies such as calculators are helpful as well as the types of accommodations used for dyslexia. Considered to be special needs students, those diagnosed with a learning disability will travel through school with an IEP for monitoring progress, describing challenges and indicating helpful assistive technologies.

Assistive Technology

In 1999, the National Federation of the Blind (NFB) filed a class action lawsuit against America Online, Inc. (AOL). The NFB alleged that AOL's Internet browser and services were inaccessible to the blind and did not comply with the accessibility requirements of Title III of the *Americans with Disabilities Act* (ADA). The NFB claimed that AOL's online service sign-up form, welcome screens, and chat rooms were inaccessible because screen reader assistive technologies could not read text hidden within graphic displays. On July 26, 2000, the NFB and AOL litigation reached a settlement. AOL agreed to make its internet browsing software compatible with screen readers, which make AOL software accessible to blind users. AOL also agreed to make the existing and future content of AOL services largely accessible to the blind, to publish an Accessibility Policy and post it on its Web site and to pursue other actions to implement accessibility features for blind users. Shortly after the settlement, President Clinton proposed a comprehensive initiative to bridge the "digital divide" by broadening access to the Web and promoting online applications that will help all differently abled persons use new computer technologies to their fullest potential.

The AOL case was decided on the policies spelled out in the ADA for the requirements of assistive technologies in schools and workplaces. Assistive technologies refer to devices, software or pieces of equipment or systems (both off-the-shelf and customized) used to increase, maintain or improve the functional capabilities of people with disabilities. This includes devices and services as well as training that help an individual to select and utilize a device or aid. Assistive technology services include evaluation, maintenance or repair and training for students, professionals or families. Assistive technologies include, but are not limited to:

- Augmentative communication devices, including talking computers
- Assistive listening devices, including hearing aids, personal FM units, closed-caption TVs and teletype machines (TDOS)
- Specially adapted learning games, toys and recreation equipment
- Computer-assisted instruction and design software
- Electronic tools (scanners with speech synthesizers, voice recognition software)

- Curriculum and textbook adaptations (e.g., audio format, large print format, Braille)
- Copies of overheads, transparencies and notes
- Architectural adaptation of the learning environment, such as special desks, modified learning stations, computer touch screens or different computer keyboards
- Adaptive mobility devices for education in labs and workshops
- Orthotics such as hand braces to facilitate writing skills

For some, existence problems associated with everyday functions require technologies such as adapted utensils, dressing aids, adapted toilet seats, and occupational therapy services. Communication problems associated with the need to receive, internalize, and express information require amplifiers, captioned video, speech aids, magnifiers, sign language training, drawing aids or alternative computer input devices. Body support, positioning, and protection problems associated with the need to stabilize the body require prone standers, furniture adaptations, support harnesses, slings, headgear or orthotic stabilizers. Travel and mobility problems associated with the necessity to move require wheelchairs, scooters, ambulators, canes, crutches, or orientation and mobility services. Environmental problems associated with needs to use equipment require special switches, remote controls, adapted ramps, automatic door openers, driving aids and rehabilitation engineering services. Education and transition problems associated with needs to participate in education require adapted instructional materials, educational software, computer adaptations and creative arts and crafts therapy. Sports, fitness, and recreation problems associated with needs to participate in sports, play and hobby activities require modified rules and equipment, adapted aquatics switch-activated cameras, Braille playing cards and adapted physical education services (Blackhurst & Edyburn, 2000). All schools and public institutions as well as most private businesses have a duty to accommodate and this requires the creative design and use of assistive technologies.

While the intention of the ADA is the removal of architectural and communication barriers, the law also requires that assistive technologies be considered in the development of an IEP. Assessment processes must provide for students to be evaluated or screened in all areas related to the suspected disability, including (where appropriate to the needs of the student) health, vision, hearing, social and emotional status, general intelligence, academic performance, communication status and motor abilities. Consideration of technologies should be an integral part of the assessment processes to ensure the IEP reflects each student's unique needs. For example, for required assignments and projects, teachers should determine how assistive technologies might allow a student to communicate and access the instructional program. A student's need for assistive technologies, training and support services must be considered on a case-by-case basis in developing the student's IEP. If the participants on an IEP team, which includes parents, determine that a student requires assistive technology in order to receive an appropriate public education and designate such technology as either an educational or related service or as necessary to maintain the student in a regular classroom, the student's IEP must include a specific statement of such services. Related services may include occupational therapy, physical therapy and speech therapy.

Disabilities legislation prohibits discrimination against disabled persons in the full and equal enjoyment of public accommodations. A "public accommodation" includes any private (non-governmental) entity, regardless of size, that offers goods and services (e.g., education) to the general public. Discrimination includes the failure to provide appropriate auxiliary aids or services (e.g., sign-language interpreters, assistive listening devices, Braille, or audiocassettes for individuals with sensory impairments) where necessary to ensure effective communication with students with disabilities. For education, digital technologies have great advantages over print media because delivery can be in multiple formats. However, the design of digital technologies for persons with cognitive, physical, sensory, and other impairments must be intentional; visually impaired students, for instance, rely on screen readers, which are dependent on text rather than graphic displays. Assistive technologies and other accommodations for special needs are essential to classroom management, safety and facilities design strategies.

Safety

In the world of work, a vast majority of accidents involve young adults between the ages 15-24. According to the Workers Compensation Board (WCB) of BC (1998), about 46 young workers are injured each day and five are permanently disabled each week. The injury rate for young male workers is 70% higher than the rate for all other workers in North America. The rate for young girls is half the average for all workers. About 80% of these accidents result in bruises, cuts and strains. There are a number of reasons for these high rates. First, adolescents and young adults have less experience in recognizing hazardous situations than older workers. Second, young workers are less likely to ask questions or question practices that look unsafe. Third, young workers, especially males, are more likely to take risks and increase the pace of their work. Some feel pressured to match the pace of their peers or other workers and generate conditions that are unsafe. The fourth reason can be attributed to employers who often exploit young workers or neglect conditions that lead to accidents. Turning to the schools, nearly all accidents can be accounted for by any combination of these. Indeed, classroom management has to necessarily account for these reasons for accidents. Technology teachers have been known to remark that a workshop in school is akin to running a business with the most inexperienced, untrained workers one can find. The conditions are ripe for incidents and accidents.

Accidents in school workshops are common—more common than should be the case. The extent of school lab and workshop injuries is generally underestimated because the submission of Student Injury Reports (SIR) by school authorities to central provincial or state health departments is voluntary. Teachers and nurses complete the SIRs and not safety professionals trained in accident investigations, and the extent of the injury is also underestimated. The best research we have suggests that 7% of all school injuries occur in technology labs and workshops. For example, in the state of Utah between 1992-1996, 14,133 students were injured and 1,008 were injured in labs and workshops (Knight, Junkins, Lightfoot, Cazier, & Olson, 2000). Nearly half of these occurred in grades 8 and 9, and 87.3% were male. About 88% of all the injuries were equipment related. Power saws accounted for about 25% of these, which some may find troubling given that the use of power saws by minors in the workplace is prohibited by law. In school workshops, no such regulations exist. To put this in perspective, across North America 40% of school injuries are caused by falls, 34% by sports activities and 10% by assaults. We do not yet have comparative data, but perhaps one of the more significant results in the transition from industrial education to technology studies was the reduction of school workshop accidents. The equipment has changed and students are placed in fewer potentially dangerous positions than three decades ago. Nonetheless, there remains a wide range of hazards in technology studies that must be managed.

There are basically three reasons for safety management. The first is moral and assumes that every technology teacher is a caring human being with an innate desire to protect those who are younger or less informed, as students usually are. The moral aspect of safety indicates that instructors should possess a natural predisposition to do what is possible to keep students safe from injury. The second reason is financial. Preventive maintenance is less expensive than litigation. "It costs more to have accidents than it does to safeguard against them," This applies to financial losses that may result from injury to students as well as to property damage, destruction of resources and tools, legal counsel, court and medical costs, fines or loss of a teaching position. The third reason is legal; duty of care and due diligence mean that administrators and teachers are responsible for the health and safety of students entrusted to their care. Students are legally under the charge and guidance of the teacher to whom they are assigned at any given time. The legal reason also refers to safety regulations and provisions required by local, provincial or state and federal governments (Louisiana Technical College, 1992). These three reasons require both philosophical and technical considerations.

Philosophically, safety ought to be oriented toward prevention but teachers must also plan for what to do as a problem is occurring and afterwards. Safety managers refer to these three stages as pre-event, event and post-event controls. Interventions can be made in any of these three stages to control an outcome, either by preventing it or minimizing any downgrading affects when a problem occurs. We should ask ourselves: What am I doing to prevent this or that accident? What will I do as this or that accident is occurring? What will I do after it occurs? The optimum strategy is to focus on the pre-event stage and anticipate any problems. "Deep knowledge," says the Taoist *Book of Balance and Harmony*, "is to be aware of disturbance before disturbance, to be aware of danger before danger, to beware of calamity before calamity…. By deep knowledge of principle, one can change disturbance into order, change danger into safety, change destruction into survival, change calamity into fortune." This is intuition—sensitivity to impending danger or probable changes (Montante, 1991, p. 32). Safety is a complex, open system involving environmental and human factors—people, resources, technologies, processes, feedback, policies, procedures, regulations—that must be balanced (DeLuca & Haynie, 2000).

Pragmatically, safety begins with policies, procedures, guidelines, and specific safety rules for individual processes. Technology teachers ought to practice with a clear and workable set of policies, rules and procedures that are written down and spelled out for students and other interested parties. Behavioral rules correspond to what you expect for setting the tone for acceptable classroom behavior. General procedures correspond to the conduct of a normal class session in your lab or workshop (e.g., 1. Enter the Lab or Workshop with a Positive Attitude. 2. Adopt a "Ready to Work" Attitude. 3. Find your Seat for Attendance and Necessary Announcements and Lesson. 4. Begin Work (Safely) on Projects, etc. 5. Be Ready for Cleanup. 6. Put your Things Away and Cleanup. 7. Exit Quietly). General safety guidelines are those that govern all activities and work in the facility under your charge. Specific safety rules are for individual devices, machines and processes (chemical, heat, mechanical, etc.) associated with any type of danger. Teachers must share all of these with their students as professional handouts and posters, and prepare to explain the consequences for violations of policies and procedures.

Do accidents just happen? How can anyone foresee them? As mentioned, accidents are caused by unsafe acts, unsafe conditions, inattentive or negligent supervisors or by a combination of the three. A key component of a safety program is to prevent harmful events in the future by assessing hazards today. This is also a critical factor in liability. This requires that teachers routinely assess the conditions of their workshops and labs, and observe students to identify and correct unsafe acts and poor work practices. This may require the close supervision of some students and additional instruction to correct carelessness, poor work habits and risk-taking. In some cases, teachers may have to discipline students to ensure that they observe safety policies and rules. Regretfully, teachers themselves are rarely disciplined for failing to carry out their health and safety responsibilities. That is, teachers typically escape discipline until an accident is combined with litigation and the liability question is raised.

Liability

Do not confuse responsibility and accountability with liability. Technology teachers are ethically responsible, whether legally liable or not, for accidents and incidents that could have been prevented in any way. Responsibility extends to all facets of classroom management, from equity to special needs, from bullying to humor, from facilities design and ergonomics to safety. Teachers can be held accountable for oversights and carelessness but not held liable. When students are emotional or physically injured under a teacher's care, he or she will feel the moral damages of responsibility regardless of any financial damages of negligence and liability.

Liability revolves around the concepts of duty of care and due diligence. Duty of care is the first standard against which a teacher is held: they must act as a "careful or prudent parent." Due diligence means taking all reasonable care to protect the well-being of those over which one has a duty of care. To meet the standard of due diligence, teachers must take all reasonable precautions to ensure the safety and health of students. In prosecutions for violations of safety and health laws, the prosecutor must prove that the accused violated standard practices or due diligence. To be acquitted, the accused must establish that on a balance of probabilities all reasonable precautions to comply were taken in the circumstances. This is the defense of due diligence. Teachers and administrators are not expected to anticipate and prevent every possible accident. They must, however, take all the precautions that a reasonable and prudent person would take in the same or similar circumstances. Courts recognize formal defenses of due diligence in prosecutions. Compliance with safety and health regulations standardized and monitored by governmental agencies such as the WCB in Canada or Occupational Safety and Health Agency (OSHA) in the U.S. is a necessary first step in defenses of due diligence. Administrators and teachers are often mistakenly under the assumption that WCB or OSHA regulations stop at the schoolhouse door. However, the WCB and OSHA consider schools to be workplaces. Students are not treated as unpaid workers. Rather, the logic is that if health and safety standards are maintained for teachers they will be by default maintained for students. If WCB or OSHA regulations are in effect and working well, a teacher will generally be able to establish due diligence. If there are specific hazards, a teacher will also have to establish that special steps in controlling this hazard were taken to show due diligence in particular circumstances. Generally, the greater the risk, the greater the need for specific policies, practices and other measures to control the equipment or hazard (WCB, 2003). Demonstrating due diligence and upholding the standard of duty of care requires an organized system of record-keeping to provide a history of activities related to safety and health regulations.

In general, in order to uphold liability claims in courts against a teacher, the plaintiff's (student) lawyer's must show that injury occurred because the teacher exceeded authority, used poor judgment, (duty of care), or failed to take reasonable precautions (due diligence) resulting in a charge of negligence and liability. As mentioned in the previous section, the best way to demonstrate that you are not negligent is to maintain an active safety program that encompasses instruction, supervision, inspection, and documentation. In litigation, the defendant (teacher) may have to provide documentation for any or all of the following (Louisiana Technical College, 1992):

1. The teacher was in the classroom when students were working with potentially dangerous materials, machines, or processes.
2. Hand tools and machines were maintained and in good working condition.
3. Each student was required to pass safety tests. Test results were filed in the teacher's records.
4. Regular inspections were made of the tools and equipment used by the students.
5. Complete instructions, including handouts, were given to students before they were allowed to operate machines. Instructions were professionally written, understood, and supplemented with oral assessments.
6. The operation of machines was supervised to ensure that equipment was operated correctly and the instructions were followed.

Table 5. (Source: Rempel, 2000)

Teacher liability safety checklist

- ✓ Well-maintained equipment with proper guards
- ✓ Safety equipment in good condition
- ✓ Adequate safety policies and procedures in shops or lab
- ✓ Student attendance records
- ✓ Adequate supervision practices
- ✓ Student safety tests on file
- ✓ Student notebook with safety and procedure sheets
- ✓ Current day book
- ✓ Visible safety posters and stickers

Legal liability depends on the existence of five elements:

- ❑ A duty of care.
- ❑ A breach of the standard of care.
- ❑ Damage or injury that results from the breach.
- ❑ Reasonable foreseeability of causation.
- ❑ Plaintiff suffered some actual loss.

Duty of care- "careful or prudent parent" related factors include:

- ❑ Number of students being supervised.
- ❑ Nature of the activity.
- ❑ Age and skill level of the students.
- ❑ Nature and condition of the equipment.
- ❑ Competency and capacity of the students.

7. Safety procedures were reviewed periodically.
8. Proper eye, face and safety protection was required for students.
9. Director, principal or Safety Committee was notified, in writing, of any unsafe conditions that were not immediately corrected.
10. An accident report was completed and included signed statements by witnesses.
11. Actively promoted safety policies in area of work.

Some technology teachers resort to consent and waiver forms for parents to deal with participation in high-risk activities. Here, the weight of deciding on the level of risk acceptable to a family is taken from the teacher and placed back on the parents. Nevertheless, the teacher is not relieved of liability by a signature on a waiver slip to approve of the student's participation in hazardous activities in the school. This may be an acceptable public relations procedure but a parent cannot sign away a student's right to file a tort liability suit. The law indicates that an injured person has the right to seek monetary damages from a person who bears responsibility for causing that injury. In carrying out their responsibilities, it is necessary that teachers exercise due care and diligence to guard against negligence. For better or worse, liability and the possibility of litigation raise the standards to which teachers and schools are held accountable..

Public school educators who are members of their teachers' federations or unions receive an educators' liability benefit. This liability benefit covers payment of the legal costs of defending civil proceedings (excluding civil rights cases) brought against teachers in the course of their work as an educator, and $1 million to $5 million in damages assessed against a teacher as a result of such proceedings. In the course of their work, technology teachers are frequently exposed to situations that may give rise to legal actions and which can involve personal liability. If a student or a student's parent(s) file suit against a teacher, this policy provides insurance protection for the vast majority of cases. The program also reimburses for damage to personal property in assault-related incidents. Fortunately, for science and technology teachers, liability protection for activities in all lab and workshop facilities is covered.

Class Size

Class sizes are linked to economics and demographics. For example, average secondary school class sizes in Canada and the U.S. increased from 20 in 1915 to 31 in 1932. Average class sizes in primary schools, traditionally higher than in secondary schools, reached 39 in 1932. In the early 1930s at any given time, New York City students were crowded in classes that numbered over 50. Industrial arts classes were no exception but IA teachers were used to large classes. They often crammed 30-40 students next to the manual training benches and there were few who escaped the effects of mass education. In the early 1970s, the baby boom combined with a recession to swell class sizes again. Currently, for mixed reasons, many technology teachers are watching class sizes increase, from a mid 1990s average of 21 upward to 30. Governments are tightening budgets and school districts are not filling vacated positions. Some are laying teachers off.

With declining enrollments in their technology courses and classes of 30 students in other subjects, technology teachers can ill-afford afford to complain. Yet without agitating for caps on class size, we face increasingly difficult management and safety issues. Class-size dynamics necessarily alter classroom management. However, economists note that there is no relation between class size and student performance (e.g., Hanushek, 1998). Given our accident reporting data, nor can we argue a relationship between class size and safety. Intuitively, it makes sense that smaller classes are optimally safe but without adequate data, we lack evidence. We may also think that instruction is individualized in smaller classes but data suggest that teachers do not readily adjust to class size. Intuitively, it seems that reduced class sizes result in fewer behavioral problems. Again, the data are incomplete with the best research concentrated on grades 1 and 2 (Finn & Achilles, 1999; Finn, Pannozzo & Achilles, 2003). What are the recommended class sizes?

Capacity and occupancy loads differ across grade levels. Middle and secondary school technology facilities are commonly 1,250-1,800 sq. ft. The Building Officials and Code Administrators (BOCA) recommend a space allocation of 50 net sq. ft. (4.6 net sq. m) per student and some governments increase this to 78 net sq. ft in secondary schools. A decrease in the BOCA allocation has to be approved by an "authority having jurisdiction" (i.e., fire marshal, state safety officer). Some teacher unions have negotiated a cap of 30-32 students for middle and 28 for secondary classes, acknowledging threats of liability. Due diligence requires that professionals who are aware of unsafe working conditions make changes to avoid an accident.

Facilities Design and Management

The large investments into industrial technology workshops during the 1920s and again in the 1960s served technology teachers well. However, forty years after the 1960s boom we are entrapped within a vicious circle. Since we have these workshops, we have to use them or lose them. But their use has determined what and how we teach. The design of infrastructure is a powerful force on the design of C&I. There is no getting around this. So we have to be careful about controlling this force lest we be completely determined by the facility we create or inherit.

Unit shops, or a workshop for a single material or technology (e.g., metalworking, woodworking), proliferated in North America during the 1920s. The number of unit shops increased in the U.S. from about 9,250 in 1924 to 22,950 in 1938. Unit shops for junior high woodworking increased by 300% (4, 250 to 10, 500) during the same period. This legacy was both a blessing and a curse. Until recently, in most of these unit shops, the material defined by the infrastructure determined the curriculum: woodworking was taught in the woodworking shops and so on. Unit shop investments of the 1920s were reinforced with huge investments during the 1960s and 1970s. For example, the *Federal Technical and Vocational Training Assistance Act*, enacted in 1960, provided $243 million in its first two years for establishing industrial and vocational education programs in Canada, and $2.16 billion through 1970. The *Training Act* covered 75% of capital expenses for provinces, mostly in the form of buildings and school equipment. Through the late 1960s and early 1970s, there was a huge IE building boom in North America with expansive additions and full IE wings added onto schools. Automotive garages, power mechanics shops and electronics laboratories were built and equipped to round out the IE curriculum. In the late 1960s, capital investments for a single shop were about $8,300 for each of the electronics, mechanics, metalworking and woodworking shops and $11,000 to equip each automotive garage. By comparison, a home economics lab cost $1,800 to equip and most academic classrooms cost less than $1,000 (Petrina & Dalley, 2003). By the mid 1970s, industrial education received 12.3% of education funding, exceeding all subject except for English.

Beginning in the late 1970s and early 1980s, technology studies began to take on the infrastructure of computer labs, often expansions of electronics, graphics and drafting facilities. At the same time, schools invested in central computer lab facilities, which partially severed information technology from the balance of technology studies in the schools. In the early and mid 1970s, individual terminals cost between $6,000-$9,000 and relied on a mainframe costing anywhere between $50,000-$80,000. Estimates for full labs (20 students) were between $200,000-300,000. The microcomputer revolution changed the infrastructure but not necessarily the cost. Apple II computers were introduced into the schools during the late 1970s and early 1980s in Canada and the U.S.. By 1981, 80,000 microcomputers were installed in U.S. schools, laboratories were assembled in the high schools of Canada and the U.S., and courses were offered in computer studies. I bought two Macintosh computers for my high school drafting course in 1984, effectively transforming the curriculum from board drafting to computer aided design (Petrina, 2003). By the mid 1990s, the average cost of labs was still about $200,000.

In technology studies, the popularity of modular facilities increased throughout the 1990s. Modular facility refers to a self-contained (i.e., "everything" is there for the student) instructional *system* defined by devices and infrastructure. This includes instructional systems ranging from self-contained packages to desktop technology trainers and kits (e.g., LEGO-Logo, Principles of Technology, Fischertechnik trainers) to architectural structures and infrastructure (e.g., Lab 2000, Synergistic Systems Labs). Currently in the U.S., 72.5% of technology education programs in public schools use teacher-made modules and 48.5% use commercially vendored modules (Sanders, 2001). During the 1990s, the commercial production of modules became an attractive endeavor for vendors who marketed their curriculum at prices ranging from $8.00 for a paper packet to $12,980.00 for turnkey learning systems (Noble, 1993; Petrina, 1993).

Both teachers and vendors reconceptualized what a technology workshop or lab ought to look like at the same time that new ideas for school architecture and infrastructure were presented in reports such as *New Designs for the Comprehensive High School* (Copa, 1992). Many teachers spent weekends and summers renovating their infrastructure for a new era of technology studies. Vendors such as Creative Learning Systems offered the most imaginative designs for technology environments with their SmartLab 2000 and Creative Learning Plaza. These are high tech versions of the general shop, combining communication, fabrication and digital media design "cells" and "islands" in a clean environment (e.g., Green, 1994). New teachers are faced with the challenges of rethinking the physical spaces of their facilities

Figure 7. Conventional row lab plan

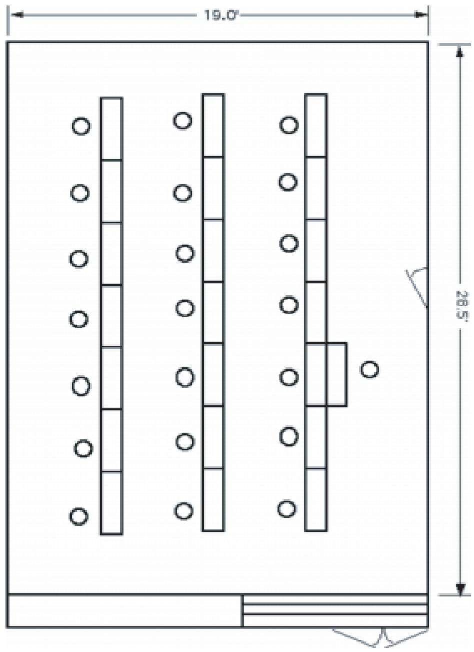
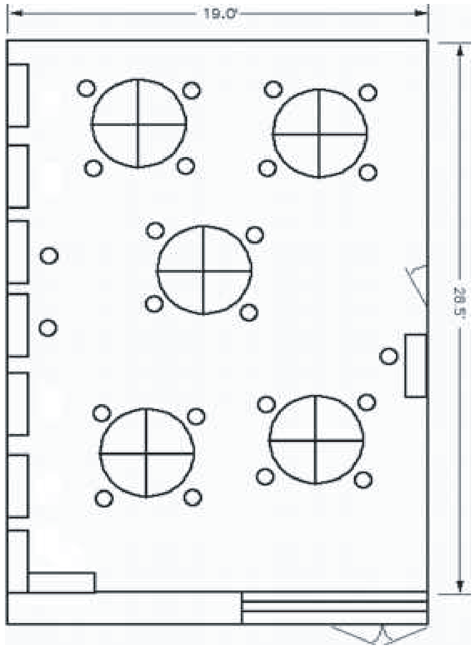


Figure 8. Island pod studio plan



to reflect their classroom management philosophies and new curriculum (Polette, 1991). One of the first tasks is gathering information on the district's small renovation and maintenance policies. Technology teachers have been the most innovative in taking advantage of loopholes. Large districts receive 15,000 work orders per year but only fill about two thirds. Hence, union maintenance specialists typically understand and tolerate changes that can be done without excessive infringements on their contract agreements.

The challenge is to think creatively about technology environments. Any workshop or lab will accommodate any combination of redesigns, renovations, and improvements. For example, following five figures describe a variety of ICT lab designs. Some present basic infrastructure challenges, such as access to power. Figures 7, and 8 require ethernet and electrical line drops from the ceiling or feeds from under the floor to network and power the workstations. The current wave of laptops offers flexibility beyond standard lab or studio designs but present their own problems of durability. T1 and ethernet still provide significant benefits over WiFi.

The double-U shaped and extended row plans (Figures 9, 10) allow for flexibility and accessibility in ways that the conventional row plan does not. Where students hide behind their monitors in the conventional row plan, the double-U and extended row plans maximize visibility. In the double-U plan, the inner tables do not have

Figure 9. Double U-shaped lab plan

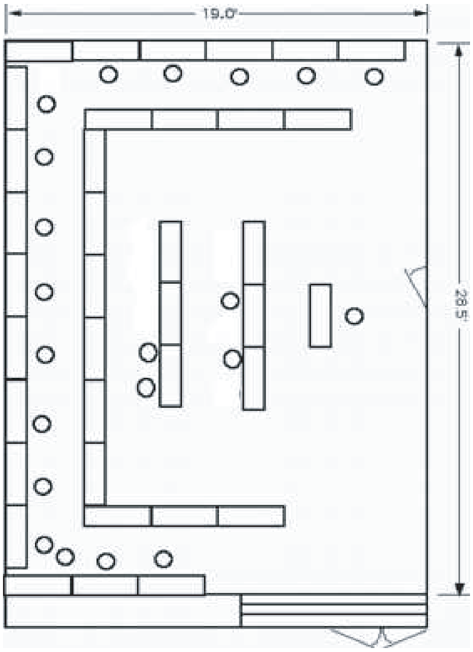


Figure 10. Anchored row studio plan

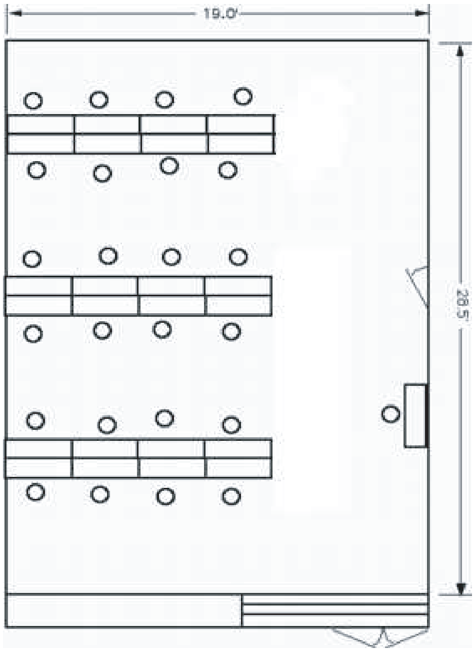
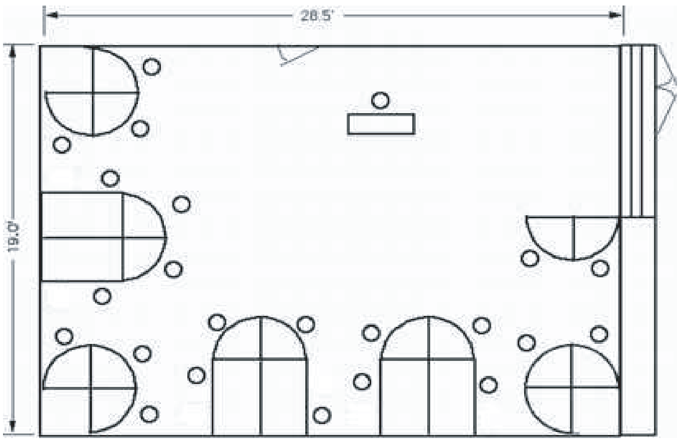


Figure 11. Tethered pod lab plan



workstations; they are placed for group work, presentation, and demonstrations at the front of the room. Students must literally turn their chairs, placing their backs to their monitors when the teacher gathers for a lesson. There is a similar effect with the extended row and tethered pod (Figure 11) plans. These are good examples of how facilities design facilitates and hinders classroom management.

As mentioned in the beginning of this chapter, a clean, well-organized facility is the

Table 6. CREATE scale of facilities and curriculum design (Adapted from Peterson, 2000)

	1	2	3	4	5	**1- Never 2- Seldom 3- Sometimes 4-Often 5- Always**
1	o	o	o	o	o	Students are intrinsically motivated
2	o	o	o	o	o	Students have original ideas
3	o	o	o	o	o	Students are enthusiastic
4	o	o	o	o	o	Students find technology to be personally challenging
5	o	o	o	o	o	Students take initiative to solve problems
6	o	o	o	o	o	Essential information is available for problem-solving
7	o	o	o	o	o	Time is allocated for students to produce original ideas
8	o	o	o	o	o	Sufficient tools and machines are available to design and produce artifacts
9	o	o	o	o	o	Sufficient materials are available to produce designs and artifacts
10.	o	o	o	o	o	Computers are available to access information
11.	o	o	o	o	o	Models and example of creative work are displayed

Table 6. continued

12.	o	o	o	o	o	The facility inspires creativity
13.	o	o	o	o	o	The facility is attractive
14.	o	o	o	o	o	Students like to work in the technology facility
15.	o	o	o	o	o	Posters of creative people are displayed
16.	o	o	o	o	o	Students are trusting and open
17.	o	o	o	o	o	Creativity is recognized and rewarded
18.	o	o	o	o	o	Students are free to choose their own approach to solving problems
19.	o	o	o	o	o	The class has a dynamic, cooperative spirit
20.	o	o	o	o	o	The class is able to critique and debate ideas
21.	o	o	o	o	o	Students use a systematic process to produce their best solution
22.	o	o	o	o	o	Students are able to generate multiple ideas and designs
23.	o	o	o	o	o	Students can elaborate and improve ideas
24.	o	o	o	o	o	Students can produce novel or original ideas to practical problems
25.	o	o	o	o	o	Students apply relevant knowledge to effectively solve practical problems
26.	o	o	o	o	o	Peer teachers support and encourage creativity
27.	o	o	o	o	o	Administrative personnel recognize and reward creativity
28.	o	o	o	o	o	Parents value the creative efforts of their children
29.	o	o	o	o	o	Creative people and role models are used as community resources
30.	o	o	o	o	o	The technology teachers models creative behavior
Total						**30-75** Environment is seldom creative; **76-105** Environment is sometimes creative; **106-150** Environment is often creative

most effective facility. This is true despite your habits at home or your inheritance from previous teachers. Facilities design specialists, such as Polette (1991), advise new teachers to adopt multi-purpose philosophies even in unit workshops. I can also attest that it pays off to take time to organize and reorganize your facility. Reallocate space for designing if necessary. Teachers have been known to collect a handful of computers, cobble them together in the form of a network and request upgrades for the design facility that administrators "forgot" was there. One measure of any technology facility is its infrastructure for creativity and design.

Facility Evaluation

Criteria for evaluating a facility ought to be fairly evident at this point: Resources and décor that promote equity and sustainability, a clean environment, safety policies, procedures and devices that anticipate problems, philosophy of prevention, ergonomic design and a flexible, forward-looking curriculum. Richard Peterson (2000) recommends evaluating facilities as a measure of creativity (see Table 6).

Ergonomics of Labs and Workshops

More than any other subject, technology studies creates conditions requiring ergonomic attention. Computer labs, studios, and workshops offer situations that require repetitive micro-movements, awkward lifting and challenging machine interfaces. Technology teachers can control certain aspects of ergonomics while other aspects are beyond control. Ergonomics or human factors is the study of interaction between people, technology and systems in their (work) environment. It includes environmental, physiological, and psychological aspects of the interaction. The goal is to find a balance between the capabilities of humans and the demands required by the technological environment. The benefits of ergonomics include increased quality and safety, as well as a decrease in musculoskeletal injury (MSI). MSI is an injury or disorder of the muscles, tendons, ligaments, joints, nerves, blood vessels, or related soft tissue including a sprain, strain and inflammation, that may be caused or aggravated by work. It includes overuse injuries such as tendonitis as well as overexertion injuries such as a muscle strain.

Ergonomic solutions in labs and workshops are often obvious, such as platforms for shorter and younger students to use certain devices or machines. Special fixtures may be necessary to basically guarantee the safe use of dangerous equipment. Although the virtues of industrial quality equipment versus equipment customized for school use or young students are debatable, equipment scaled down for young students results in a better ergonomic fit. This reduces anxiety and produces greater confidence, making for a safer environment. Desktop equipment was built for light duty work and educational objectives; it was never designed for industrial use. Teachers may have to increase the visibility of buttons and switches or audibility of alarm, warnings, and signals to respond to ergonomic problems. Most technology teachers find themselves constantly addressing problems of traffic flow, which test even the most seasoned of ergonomic psychologists. Other ergonomic challenges may not be so obvious, such as monitoring students in computer labs for repetitive strain. Given that health researchers are documenting more and more strains in younger and younger students, technology teachers have a responsibility to monitor the conditions under which their students work. Signs such as swelling, redness, difficulty moving a particular body part or clenching hands may suggest ergonomic problems. Students may report symptoms such as numbness, tingling sensations, or pain, which can clue teachers into ergonomic problems. Of course, the best intervention is prevention.

Ergonomic specialists recommend that teachers monitor repetitive use and duration of use of devices, tools and machines for their students. Teachers may view the use of preventive measures such as rest and recovery cycles or stretch breaks as overkill but the bigger picture means that students habituate the importance of these measures in their lives outside of school. Forces required for the use of certain devices, tools and machines are reduced by upgrading and maintaining the equipment. The provision of fixtures and jigs to support work items may have to be provided to resolve ergonomic problems. Students have to be taught proper techniques for handling objects and work pieces, using digital equipment and working with machinery. For reasons of safety and ergonomics, teachers must do what is necessary to decrease stress and stressful situations. Teachers are responsible for maintaining a comfortable work environment free from stressors.

Budgets and Inventories

Funding cycles for the acquisition of curriculum and instructional resources begin at the federal, provincial and state levels. Funds are then allocated to districts (budgets, grants, trust accounts) and then redistributed from the district to the schools (operating and trust accounts). On top of everything else, teachers must understand how funds are allocated in order to facilitate their own budgeting process. Some districts and schools use site-based management to make budget decisions while others use very centralized models. Budgets are developed through accounting systems such as zero-based budgeting, line item budgeting, performance budgeting, etc. The purpose of the budgetary process is to determine unsatisfied needs, to devise strategies for meeting those needs, and to provide fiscal and program accountability. When developing a budget for the acquisition of resources, school districts and teachers can (BC MOE, 2000):

- Budget for the purchase of learning resources that support the implementation of the K-12 curriculum
- Budget for the purchase of newer learning resource formats and ICT
- Budget for the purchase of expensive items, unusual items, and/or other curriculum-related items for loan to schools

- Develop per student or per school allocations or other processes for providing equitable funding
- Make projections of future learning resource needs and build long- and short-term budgets to support the acquisition of resources
- Use a consultative process to develop a comprehensive budget for purchasing learning resources
- Evaluate the impact of previous budget decisions
- Align with federal, state, district, and school policies and procedures for resource funding

In most cases, an inventory will accompany the ordering process. Some teachers prefer to keep an on-going inventory, documenting the progressive consumption of materials while others prefer an annual inventory. Most teachers despise the record keeping that inventories demand, but accept the process as part of their obligation toward facilities management. A good inventory should:

- Indicate missing, lost, or damaged items
- Identify resources in need of replacement
- Indicate gaps in the collection of materials and resources

Ordering and purchasing follows the budget and inventory practice. The primary goal of the purchasing is to acquire resources and to make them available as quickly and efficiently as possible. Some districts will require competitive formal bidding, while others allow more flexibility in the choice of vendor. The most organized districts provide a system for aggregating and centralizing purchases in order to drive down costs. Teachers across different schools who combine purchase orders find significant savings. Vendors respond to bulk orders, which also has an impact on the purchasing of learning resources. Most districts have a timeline for their yearly purchasing cycle and it is up to teachers to frequently monitor the timeline. They have to stay aware of policies and procedures for the requisitioning and purchasing of resources (e.g., fiscal year carryover) and be aware of costs associated with donations (i.e., cataloguing, processing, repair, storage). Most technology teachers maintain a file to quickly access current resource information (e.g., vendor catalogues, Web sites).

For ICT, licenses must be negotiated with vendors and again, volume drives down costs. The biggest mistake that districts make is decentralized orders of software. Rather than mass licensing, most districts make the mistake of individual software packages, which are costly and redundant. Key servers are available to limit the use of software while making it accessible to a wide pool of students or teachers. For example, a key server can distribute an expensive package such as 3D Studio Max, allowing for a limited number of users at any given time but also rendering it accessible to anyone with access to the server. Currently, many teachers are reconsidering their investments into commercially licensed software and operating systems and are exploring open source software. Open source software, such as the operating system Linux, is encompassing more and more applications. OpenOffice will do what Microsoft Office does and it is free. Mozilla and Firebird browsers are popular across the world, and include built-in Web design applications, actually an upgraded Netscape Composer. Gimp is an effective Open Source graphic file manipulation package, the standard Open Source CAD programs are ArchCad and Qcad, and Blender is a powerful 3D modeling and animation application. Open Source is allowing schools to avoid costly cycles of investments into expensive software packages.

Projection and Reflective Practice

In the previous chapter, we dealt with assessment and evaluation. Some teachers suggest that an assessment system of penalties and rewards is the basis of classroom management. However, in this chapter, we noted that classroom management is dependent on a range of components including facilities design and safety. Classroom management requires a philosophy that accounts for the gender and diversity, cultural backgrounds, students with learning and physical disabilities and a range of common incivilities that occur on a daily basis. One of the most effective approaches to classroom management involves discipline with dignity. More than a series of rules and procedures, which are absolutely necessary, discipline with dignity offers a philosophy for dealing with behavioral problems. Similarly, safety requires a philosophy that focuses on prevention but responds to events and post-event situations that invariably occur in technology facilities. And the fact is that some labs and workshops work better than others for technology teachers. Some are more future-oriented and progressive than others. All facilities are *not* equal. Some make classroom management difficult by design while others create ergonomic and safety nightmares. As R. Buckminister Fuller once said, “Reform the environment; stop trying to reform people. They will reform themselves if the environment is right.” “Reforming environments” is what makes technology teaching so challenging and rewarding. “Putting it all together” is the hallmark of professional practice.

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Glossary

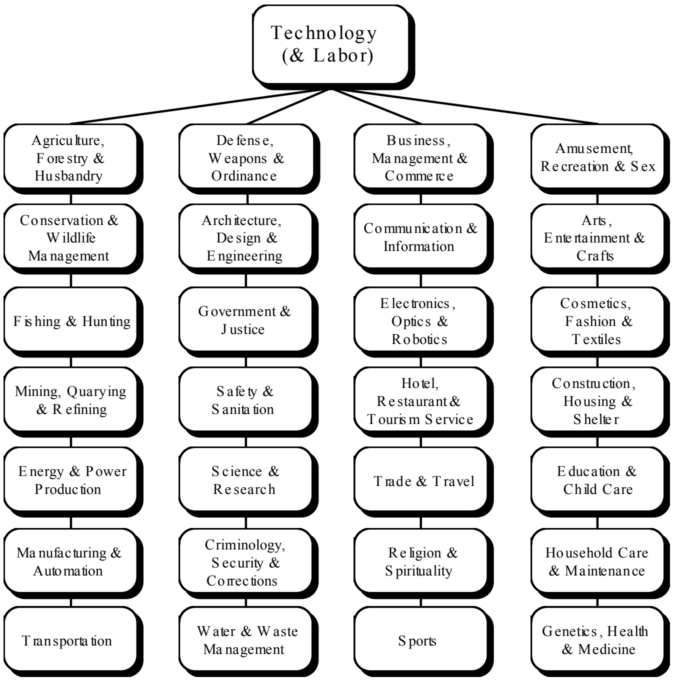
At some point, someone is going to ask you "what is technology studies?" Or what is technology education? Is it engineering education? Is this different than educational technology? Or from career and technology studies? And design and technology? In fact, Mark Sanders hosted a session at the International Technology Education Association's annual meeting in 2005 to address this issue. The scenario was this: You are in an elevator and someone asks "what do you do?" You reply, "I'm a technology teacher." They respond with the query, "what is a technology teacher?" How will you answer? What language will you choose to define your profession? Technology and design are themselves difficult to define. How will you define design or technology for your students? Define them in cognitive terms, such as problem-solving ability, and you exclude their socio-cultural dimensions. Define them in technical terms and you exclude their ecological dimensions.

Perhaps some of the most important challenges for teachers is defining their subjects. For example, the International Technology Education Association and the International Society for Technology in Education are currently trying to define the differences between educational technology and technology education. But they are overlooking the similarities, as I pointed out in an essay titled "The Educational Technology is Technology Education Manifesto" (Petrina, 2003a). In some very fundamental ways, teaching is a matter of definitions.

Technology refers to "the systematic, purposeful manipulation of the material world. It has four components: materials, technique, power, and tools or machines. Thus technology is the process of applying *power* by some *technique* through some medium of some *tool* or *machine* to alter some *material* in a useful way. These components are necessary and sufficient to describe any technology at any time, but they are static; they do not address technological change" (Roland, 1992, p. 83). Technology can also be defined as "the means and processes through which we as a society produce the substance of our existence. Specifically, technology consists of five items" (Bernard, 1985):

- *Tools (hammer, presses, typewriters)*
- *Energy forms (steam, electricity)*
- *Materials (plastics, metals, fiber optics)*
- *Techniques (weaving, annealing metals)*
- *Organization of work (assembly line, craft production, batch processing)* (p. 8)

Figure 1. Economic sectors in technology

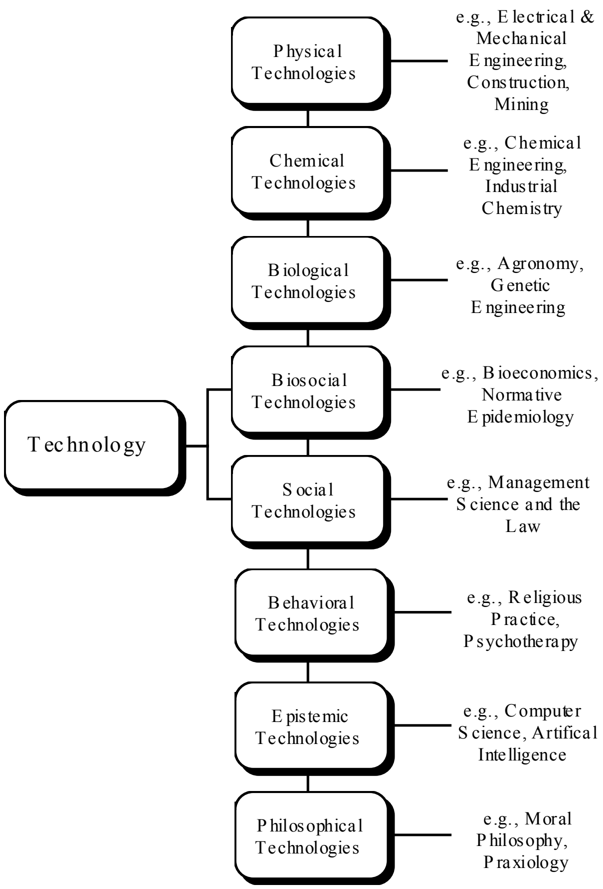


Technology, as product and service, or as activity and as knowledge, pervades every economic sector. Think comprehensively when you think of labor and technology (Figure 1).

As explained in Chapter VIII, the way we define technology determines the scope of the technology studies curriculum. Narrowly define technology and the scope of the curriculum will be limited. Broadly define technology and the scope will be expansive. Philosophers of technology have been interested in the definitions of technology at least since the ancient Aboriginal, African, Chinese, Greek, and Egyptian philosophers began to make sense of their worlds. Currently, technology is divided into eight branches (Bunge, 1999) (Figure 2).

Technology studies refers to subjects that at one time or another were collected under technical education (i.e., design, educational technology, engineering, industrial education, information technology, technical education, technology education, or

Figure 2. General branches of technology (Adapted from Bunge, 1999)



vocational education). This interpretation of technology studies, as a collective of disciplines, is represented in the *Journal of Technology Studies* and *Technology Studies*. Technology studies has recently come to refer to an even wider range of subjects. In Alberta for example, "Career and Technology Studies" includes subjects that range from agriculture to design and digital design, enterprise and innovation, fashion, information processing and marketing to tourism and wildlife management. This collection includes twenty-two subjects and is probably the most comprehensive interpretation of technology studies.

Technology studies also refers to the anthropology, economics, history, philosophy, politics, psychology, and sociology of cyberculture, technology, and technoscience (Petrina, 1998, 2003b). Work in this interdiscipline continues a tradition of both celebratory and critical studies. Over the past two decades, technology studies has challenged traditional understandings of technology, and has been working to undermine problematic technological practices in Australia, Britain, Europe and North America. For example, technology studies informs empirical questions of interrelations between science, technology and capitalism, or between human agency and social process in the design of new technologies. Research in technology studies deals with issues such as cyberculture, design, and the media, or technological threats to freedom, labor or privacy. Questions of how participation in technology is mediated by class, disability, gender, race, and sexuality are of prime importance.

Most consider technology studies (TS) to be a necessary check on science studies, hence the TS in STS (Science & Technology Studies). This interdiscipline came neither from physical science nor from engineering, but was a hybrid constructed out of the humanities and social sciences. The major tenet of Technology Studies is that technological practices, such as ICT and cyberculture, can be studied and not merely promoted as one might find in many educational institutions, IT professions, engineering, computer science, or other scientific disciplines.

Technology studies, then, refers to the spectrum of formal ways that we learn *about, through* and *for* technology—from disciplinary to interdisciplinary approaches, from applications to implications. The operative theme of technology studies is *technological pluralism*—the study of (but not the celebration of) *all* technologies and orientations to technology (alienation, instrumentalism, technoenthusiasm, technophilia, technophobia, luddism, technocriticism, etc). This range or this spectrum is what makes this field so interesting and important. In technology studies, technology is taken as a serous subject of study. Technology is *central* to technology studies. Technology is *incidental* to a large range of other disciplines, as well. Rather than the primary subject of interest, technology is infused into the practices of disciplines. And, since technology is ubiquitous, meaning it is everywhere, we also learn about and through technology by immersion and interacting with it on a daily basis. Our movements and minds are shaped by technology, through media, mass media, rules, cyberculture, or infrastructure. We learn about, through and for technology whether we want to or not (Figure 3).

Figure 3. Formal and informal ways of learning technology

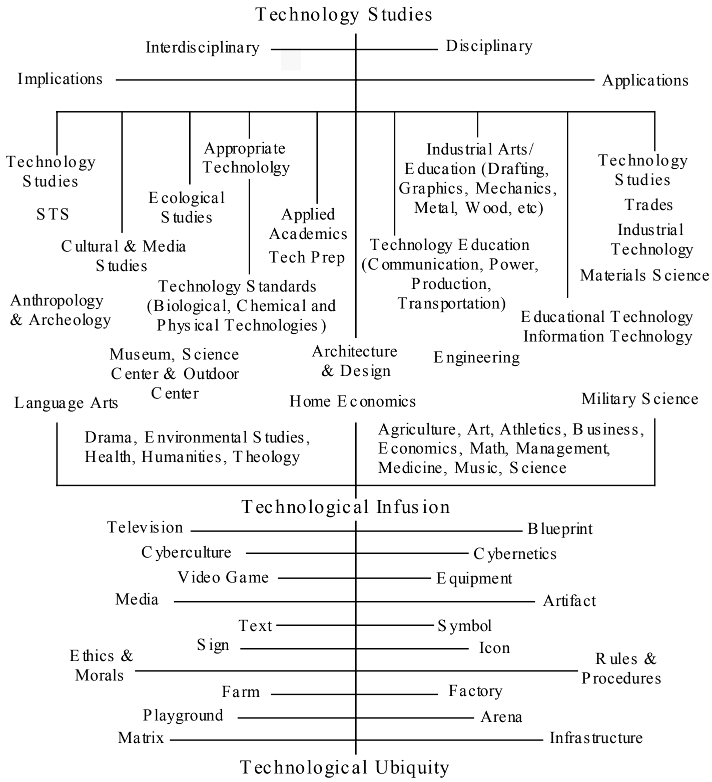
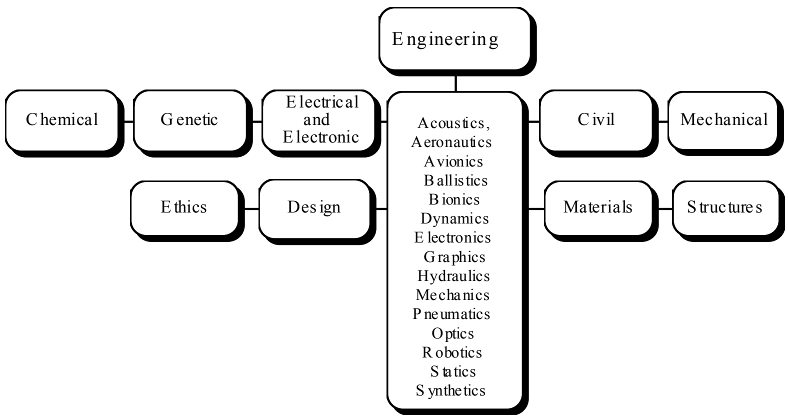


Figure 4. Engineering



Engineering is a discipline and professional practice that deals with the design of dynamic and static devices, materials, and structures (Figure 4). It consists of chemical, civil, electrical, genetic, and mechanical subdisciplines as well as others more specific to practice such as acoustics, aeronautics, and synthetics. Except for the few prep schools that focus on engineering, the presence of engineering as a school subject has been limited in North America. In the early 1970s, the Engineering Concepts Curriculum Project was initiated as way providing students in the U.S. a basic understanding of engineering and a form of technological literacy (Chapter VII). Since the 1970s, there was a rapid growth of industrial technology programs in post-secondary colleges and many of these programs were transformed into engineering technology programs during the 1990s. Engineering technology is an applied practice established in response to the theoretical emphases of engineering in the universities. Many proponents of engineering technology claim that this ought to be the main discipline of technology studies.

Industrial technology refers to the industrial sectors of the larger field of technology *and* to a subject. For example, the industrial technology sector serves economic functions that differ from the domestic or health sectors. Most limit the industrial technology sector to goods and services within construction and manufacturing. Industrial technology also refers to the postsecondary field of study that was organized in the 1960s as a complement to engineering, as a field to prepare people who knew the techniques of production as well as the practices of management. The field was positioned at the point that intersects engineering, the trades and management. Hence, it is often described as a field with an ideal balance of practice and theory. The same has been said of engineering technology, a more recent field that is linked to industrial technology. While there may be a balance of practice and theory,

Figure 5. Industrial Technology

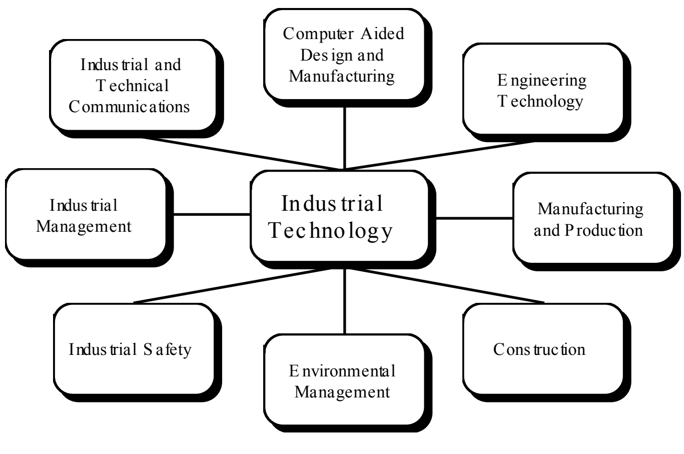
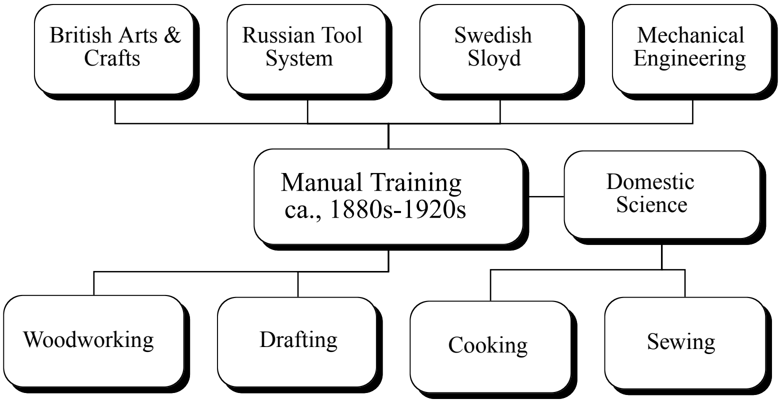


Figure 6. Manual training

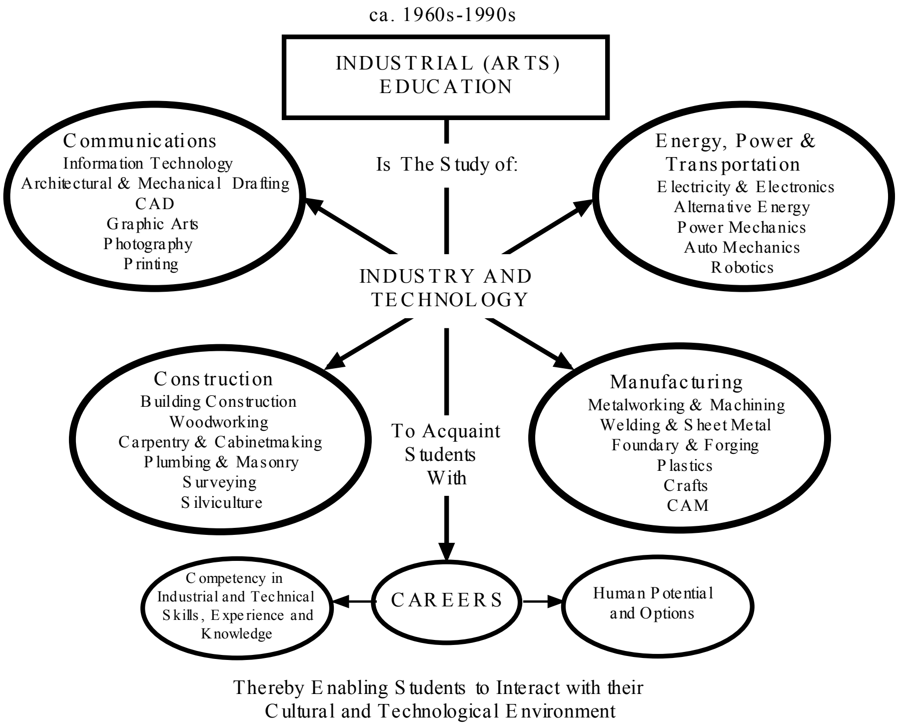


industrial technology and engineering technology are well out of balance in their overemphasis on applications and neglect of implications (Figure 5).

Manual training (MT) was introduced into North American schools during the late 1800s, and consisted of handicraft with wood and board drafting for boys, and domestic science or cooking and sewing for girls (Figure 6). MT was a convergence of British Arts and Crafts, the Russian Tool System of instruction, Swedish Sloyd approach to woodwork, and mechanical engineering. The goal was to prepare students for an increasingly industrialized world, or what amounted to a form of industrial literacy and machine grammar (Stevens, 1995). MT was an integral component of general education, as opposed to vocational in intent, and introduced working class skills and technologies into the public schools. MT was vulnerable to vocationalization and partially yielded to technical education and differentiation of curriculum or tracking and streaming.

Industrial arts (IA) or **industrial education** (IE) is a school subject that deals "experientially with technology—its evolution, utilization and significance; with industry—its organization, materials, processes and products; and with the benefits and problems resulting from the technological and industrial nature of society" (Figure 7). IA was introduced into the schools during the 1910s, following three decades of manual training and technical education which were introduced into the schools during the 1880s and 1890s (see Chapter VII). IA expanded MT from handicraft with wood and board drafting to include production with industrial machinery during the 1920s. IE was an expansion of IA in the 1960s. From the 1960s through the 1990s, IE and IA were commonly recognized by material and process-based workshops: automotive mechanics, drafting, electronics, graphics, metalworking, power mechanics, plastics and woodworking. Technical production was emphasized in IE and IA and the cultural intent of these subjects was reduced to little more than check and balance sheets. However, there was a fundamental cultural intent in this

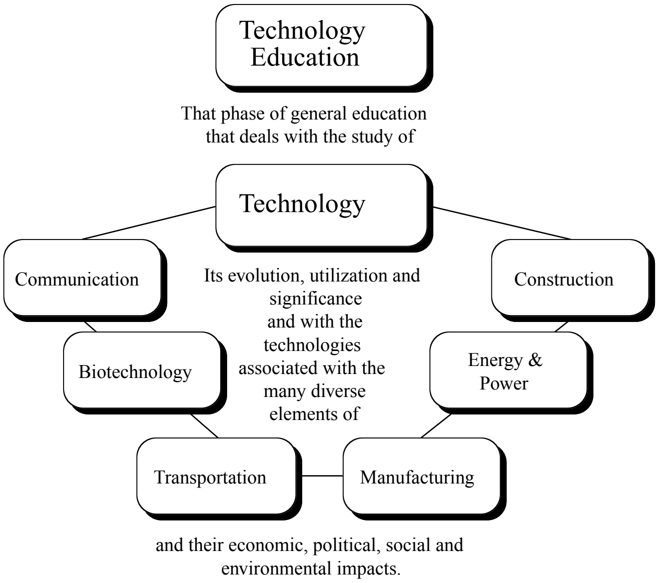
Figure 7. Industrial (Arts) Education (AAIA, 1982)



subject from its inception in the 1920s. The subject's most articulate advocate in the 1920s and 1930s, defined IA as "the study of sources of materials, methods of changing materials, factory organization, inventions, employer and labor cooperation, distribution of products, and regulative measures to secure justice alike to producers and consumers" (Bonser, 1930, p. 2).

Technology education (TE) is a school subject concerning knowledge in designing, creating, using, maintaining, regulating, and recycling technologies (products, processes and services) (Petrina, 1998). In 1991, Donald Maley defined the subject as: "That phase of general education that deals with the study of technology, its; evolution, utilization and significance; and with the technologies associated with the many diverse elements of construction, manufacturing, communications, energy, and their economic, political, social and environmental impacts" (p. 1). Similarly, TE was defined in the *Carl D. Perkins Vocational and Applied Technology Education Act of 1990* as "an applied discipline designed to promote technological literacy which provides knowledge and understanding of the impacts of technology including its organizations, techniques, tools and skills to solve practical problems and extend human capabilities in such areas as construction, manufacturing, communication, transportation, power and energy" (Public Law 101-392, Title V, Part C, Section

Figure 8. ITEA's Organizers for Technology Standards



521, p. 39). As indicated, the subject is identifiable by its organization of subjects in biotechnology, communications, energy and power, production (construction and manufacturing), and transportation (Figure 8). Most recently, within the ITEA's *Standards for Technological Literacy*, information, physical, biological and chemical

Figure 9. ITEA's organizers for technology standards (Adapted from ITEA, 1996)

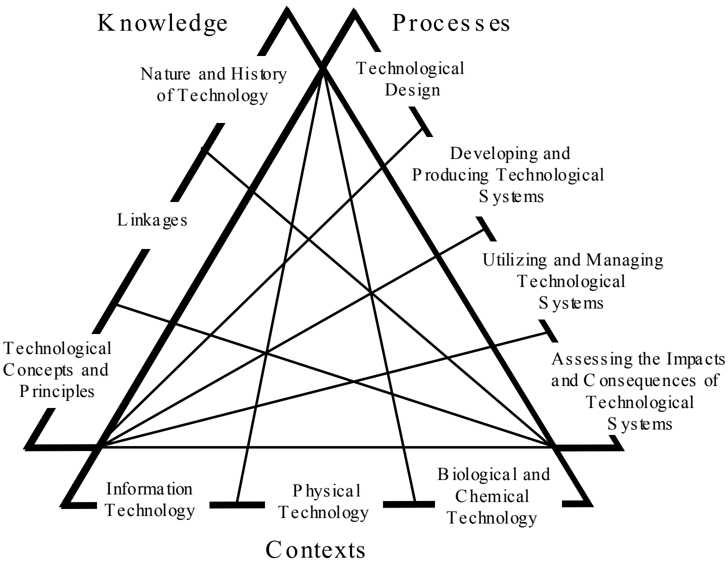
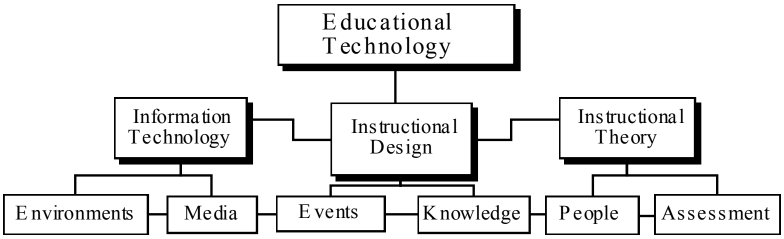


Figure 10. Audio-visual education



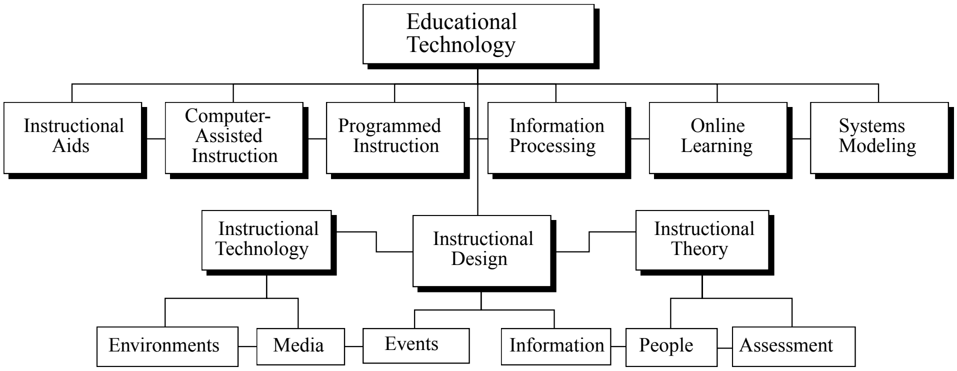
technologies were used for organizers (Figure 9). TE deals with animation, computer aided design, information and communication technology and digital video, and there is little reason to differentiate between technology education and what has been called educational technology.

Audio-visual education (AV) began as a response to the proliferation of visual resources created for education during the late 1800s and early 1900s, and the introduction of motion pictures and radio into education during the 1920s. Educators were initially interested in the production of AV aids for teachers and AV effects on students (Figure 10). However, high schools began to develop infrastructure and studios for AV programming, production. recording and repair. Through the 1950s and innovations with teaching machines, computers, and systems theory, AV morphed into technology education and educational technology (Petrina, 2003).

Educational technology (ET) has a wide range of connotations and generally refers to any use of technology for teaching and learning (e.g., books, computers, projectors, etc.) (Petrina, 2003) (Figure 11). ET basically derives from Audio-Visual Education, where artifacts such as AV materials, projectors, and teaching machines constituted the discipline. In universities, educational technology continues this tradition of instructional design and the current focus is on Web-based instruction and the efficient use of technologies for learning. ET has lost its currency, hence in countries such as Canada, England, and the USA, ET is referred to as information technology, information and communication(s) technology (ICT), or technology education (see Chapter VIII, Figure 2). Some teachers have moved from a neglect of design tools and implications to an integration of design and information. ET deals with a variety of design tools and hence the new trend in switching the combination of words from ET to TE. These blurred boundaries are evident in schools where content and practices in ET and TE are indistinguishable (Petrina, 2003). The pioneering work of Seymour Papert and the MIT Media Lab had much to do with the blurring.

Information technology or information and communication(s) technology (ICT) spans most economic sectors. Given the intensive automation that is currently taking place

Figure 11. Educational technology

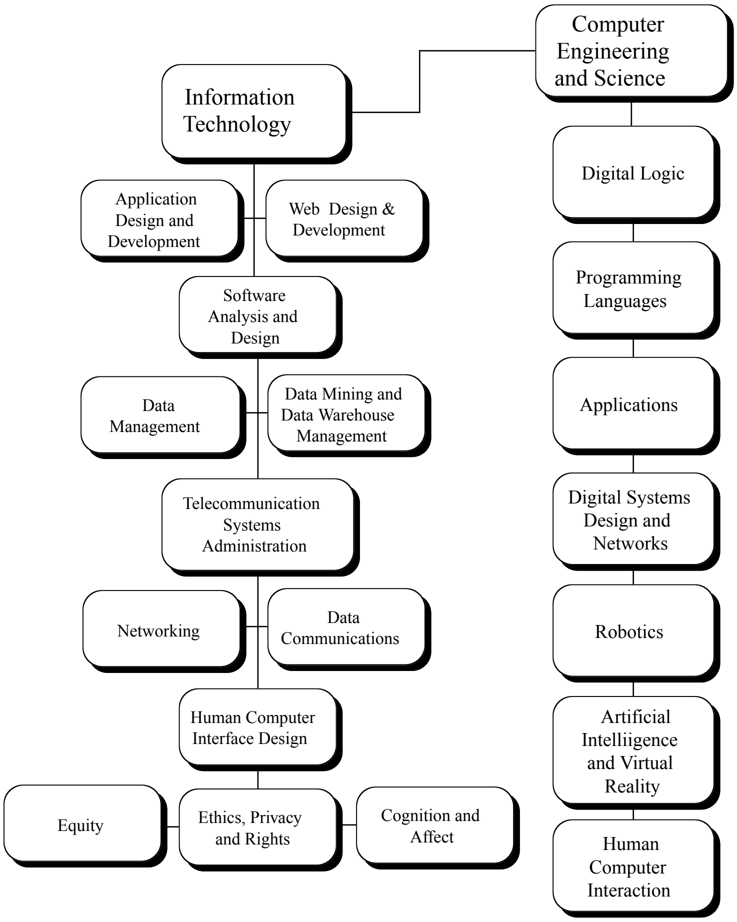


in industrial technology and service, ICT is currently the fastest growing economic sector. As a field of study, information technology is a sub-discipline of computer science, business management and engineering technology and a school subject. In the schools during the late 1970s and 1980s, courses called computer science or computer studies continued the practices of educational technologists, whose focus was on programming and applications. While a general literacy was advocated, little was done on the issues of implications. The courses were renamed information technology in the early to mid 1990s. In BC for example, the computer courses were renamed in 1996 when computer studies had little currency. Like computer science and studies, information technology reflects preoccupations with applications and in business education is information technology management. Currently, the *term* (not the practices) "information technology" is losing its currency, as most researchers argue that the new digital technologies extend well beyond information and communication. They engage a wide range of actions and are not merely conveyances of information with technology. New media is becoming the new term of choice. In the universities, cultural studies of information technology and of cyberculture are part of a larger practice of technology studies (Figure 12).

Digital media design can be defined as simply design of, and with, new media (Figure 13). New media reflects the convergence of communication, media, and information:

- Technologies (camera, computer, copier, fax, messaging, phone, printer, audio and video player etc. convergences)
- Modalities (image, print, sound, etc. convergences)

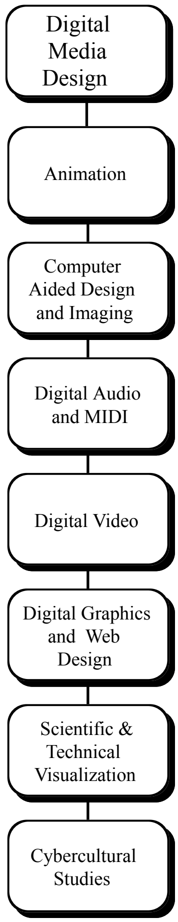
Figure 12. Information technology and computer science



- Practices (art, communication, design, fashion, film, marketing, media, medicine, programming, technology, etc. convergences)
- Corporate formations (cable and internet providers, music, newspaper, radio, and television convergences)

Digital design refers to a branch of electrical engineering that deals with the design of digital hardware. However, the accessibility and applicability of software accompanying the convergences noted have resulted in a new knowledge worker and a new field of discourse, practice, and study. Like industrial design, new media occupies a necessary space between art and computer engineering and science.

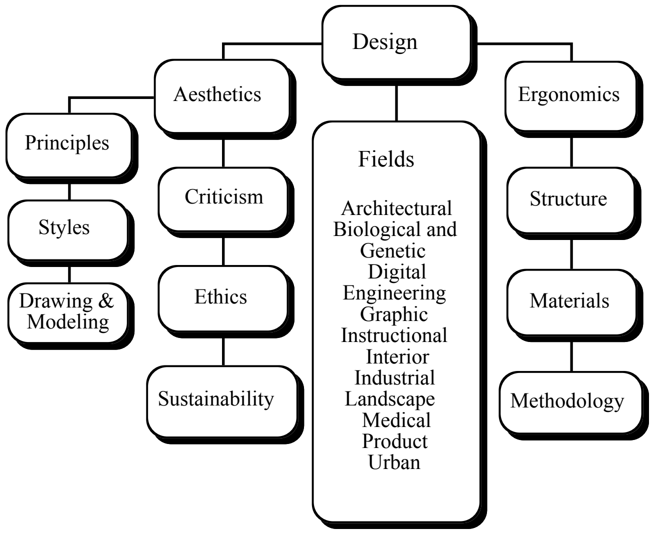
Figure 13. Digital media design



New media focuses on the design of animated and interactive content for the internet, TV, CD, DVD, and other media environments. New media create experiences environments with time-sensitive data. New media involve the design of interactive, malleable, and motion and sound oriented messages, and expand to bidirectional communication in which content responds, adapts, and changes in response to users, hosts, or circumstances. Motion allows content and form to utilize an added dimension of time to transform the capacity of still images while sound provides additional sensory capacities. New media or digital media design signifies the new digital curriculum in the schools, such as animation, Web design, and video, and has more currency than IT or ICT in education.

Design can be simply defined as "a structure adapted to a particular purpose" (Figure 12) (Perkins, 1986a, p. 2). But this definition fails to capture design as a process, as

Figure 14. Design



knowledge or as a field of study. Design is both a mode or model of technological practice, and a discipline or field of study. Design is a source of philosophical and practical knowledge regarding problems of aesthetics, ergonomics, health, function, structural integrity, and sustainability. It provides guidelines for successful construction or deconstruction, as well as criteria for discerning intent and quality, or the "workable" and "non-workable," in technology. Design organizes knowledge embedded in cultural tools such as engineering tables, drawings and models, heuristic strategies, efficiency calculations, reliability, recyclability, and safety ratings, and user surveys attuned to physical or sexual differences.

Of course, a unified notion of design does not exist, and as a rule, the more concrete the idea for an artifact, image or process, the more direct design knowledge becomes. Perhaps the Bauhaus came closest to connecting architectural, engineering, fashion, graphic, interior, product and urban design within a single fund of knowledge and style. Today, engineering design is generally a source of structural and material knowledge, while disciplines like architectural and product design are sources of aesthetic and ergonomic knowledge. Biotechnical and therapeutic design are sources of knowledge concerning agri- or aquaculture, health and medicine. Philosophies like appropriate or intermediate technology, user-centered design, integrated and participatory design, concurrent engineering, and product life cycle represent tangible visions for transforming the immediate ground of technological design.

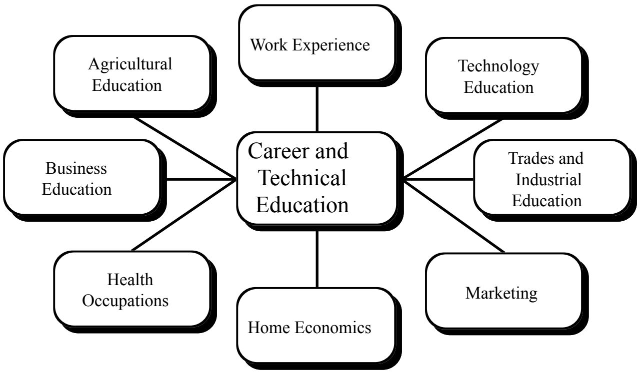
Design in the schools is typically claimed by two subjects: art and technology. For the most part, neither of these subjects does justice to the practice and theory of design. Art deals with the elements and principles of design, most often with an emphasis on graphic or visual arts. Rarely are these principles applied to the production of functional artifacts. Technology, on the other hand, traditionally dealt with the production of artifacts but placed little emphasis on design. Artifacts were not so much designed as built and duplicated.

Design and technology is a school subject that emphasizes *design* in the study of technology (knowledge in designing, creating, using, maintaining, regulating, and recycling technologies—products, processes, and services). Design and technology (D&T) is most prevalent in Australia, England, Ireland and Wales and is found in a number of schools in the US and Canada. D&T has its origins in the craft, design, and technology (CDT) programs initiated in England during the early 1970s to unify the workshop and lab-based technology subjects in the British schools. CDT was intended to amalgamate handicraft, or a concern with all aspects of artifact production, with design, or a concern with applied theory, and practical know-how (Chapter VII). D&T continues to emphasize design and creativity, but, like technology education and educational technology, minimizes the cultural and social implications of design and technology. CDT in England, beginning in the 1960s, aimed to change this isolation of design from technology. Today, design and technology in Australia, England, Ireland, and Scotland continues the tradition of CDT in the schools with an emphasis on the design of artifacts but not the design of sustainable lifestyles. Advocates of D&T note that all students ought to have an opportunity, as part of their general education, to design and make functional objects under the direction of a teacher. D&T is part of what it means to be a well-rounded person. There are few pretensions that D&T will have vocational pay-offs.

Vocational Education, which referred to career education, work education or workforce preparation, has generally been replaced by Career and Technical Education. For instance, the venerable America Vocational Association (AVA), established in 1926, changed its name to the Association for Career and Technical Educators (ACTE) in 2000. Career and Technical education typically refer to a range of subjects that extend from agricultural education to trades and industrial education (Figure 15). At the upper levels of high schools, many consider technology education to be part of career and technical education. "Career and technical education" is more appropriate than vocational education for a "post-industrial" era. Rather than an industrial model of vocational education, the new vocationalism positions technology studies as pre-engineering, pre-high tech trades, technical preparation, or "tech prep," for technical careers (Colelli, 1995). In the tech prep model, technology courses in the secondary schools are aligned with the curriculum of colleges and institutes of technology courses to ease transitions. In the best case scenarios, tech prep courses are accepted for post-secondary credits and skills developed are transferable to the technical careers of interest.

Trades and industrial education (T&I) refers to a specific form of vocational education in the trades. Trades education is defined by a long tradition beginning with the

Figure 15. Career and technical studies



English Guild system of the Middle Ages and extending to modern apprenticeship systems. For most of the twentieth century, trade unions enjoyed a large amount of control over the education of apprentices, but that is changing under neo-liberal governments. T&I educators typically position themselves on the side of trade unions and see the high schools as pre-trades education. In this scenario, technical careers and trades legitimate and validate technology studies. The trades confer status for these teachers. Most economic forecasters predict a shortage in the trades in North America over the next decade, but the numbers will never be adequate to justify the existence of technology studies in the schools. For example, only 2.5% of the students in BC secondary schools have any desire to make a transition into an apprenticeship program after graduation, and only 1.3% actually enroll in an apprenticeship program while in school.

With that much said, technology *in* education reminds one of the Philosopher's Elephant, a parable derived from the second century BC and spread through Islam by Sufi theologian Muhammad al-Ghazzali in *Theology Revived* (Rhys Davids, 1911). The parable was popularized in Islam by the Sufi Master Rumi and in the west by John Godfrey Saxe. In the story, six people are challenged to describe an elephant from a part of the elephant that they immediately *perceive*. Each one touches a part of the elephant, the reality of what they perceive and ultimately *conceive* is distorted by their interests. One from the group standing behind the elephant touches the tail and describes a rope. The second touches the trunk and describes a snake. The third touches the tusk and describes a spear. The fourth touches the leg and describes a tree. The fifth touches the side and describes a wall. The last person touches the ear and describes a fan. Not one of the six could conceive of the elephant from their narrow interests. Some who look at technology, in our case, see design, educational technology, technology education, or trades. Others see applications for art or science. Still others see information technology or communication. The disciplines merely grope for a component of the larger picture. Technology Studies, on the other hand, in its interdisciplinary nature and pluralism, provides for a collective of the disciplines and the bigger conception or picture of technology.

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