# Making Thinking Conscious: An Exploration of how Learning to Code Supports Students in Building Metacognitive Skills

by

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## Abstract

Coding (computer programming) has been entered into the BC curriculum as an essential 21st century skill for students. While having at least a beginning ability to code is a valuable skill on its own, the process of learning to code may also hold the potential to teach students valuable thinking skills. Metacognition can be understood as the ability to be aware of and regulate one's own thinking. Inspired by my own rich experiences of learning to code, and by students' positive responses to coding in the classroom, this qualitative study looked at how learning to code can assist students in building metacognitive skills. It examined how students' metacognitive skills emerged throughout the study.

Prior to beginning a coding unit, students in my grade 5/6 class reflected on their own thinking, and completed several tasks designed to assess metacognitive skills. Students then studied and practiced coding using Scratch, an online, block based coding application; they also engaged in reflection and follow-up activities designed to build awareness of and a clearer ability to communicate their thinking. Some of these activities were collected as samples and assessment data. After completing the unit on coding, students completed a similar assessment as at the beginning of the unit, and responded to reflection questions about their learning.

Student work, reflections, and assessment demonstrated increasing metacognitive skills throughout the two-month unit. Specifically, students demonstrated increased use of metacognitive skills, and a growing ability to clearly describe their skills. Students also self-reported an increased ability awareness and use of metacognitive skills, and an associated sense of confidence and empowerment. Findings suggest that learning to code may be useful for supporting student development of metacognitive skills.

**Key words: coding, metacognition, cognition, thinking skills**

# Table of Contents

## List of Tables

## List of Figures

## Acknowledgements

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## Dedication

To my students, for getting almost as excited about coding and metacognition as I am, and to my DLC colleagues and instructors, for support and friendship along the way.

"But I see much deeper and broader reasons for learning to code. In the process of learning to code, people learn many other things. They are not just learning to code, they are coding to learn." – Mitch Resnick (2013)

**Prologue: Connecting Metacognition and inquiry**

I created the image in figure 1 to illustrate the cognitive and metacognitive process. The outside circle represents a frame, or foundation, inside which metacognition sits. Metacognition is supported by our cognitive experiences that precede conscious cognitive awareness and regulation, by the cognitive tasks we complete without the need for conscious regulation, and by the task skills and knowledge we apply in a given situation. The inside puzzle represents the four essential processes of metacognition, which cyclically build on each other to enable conscious expression and regulation of our thinking.

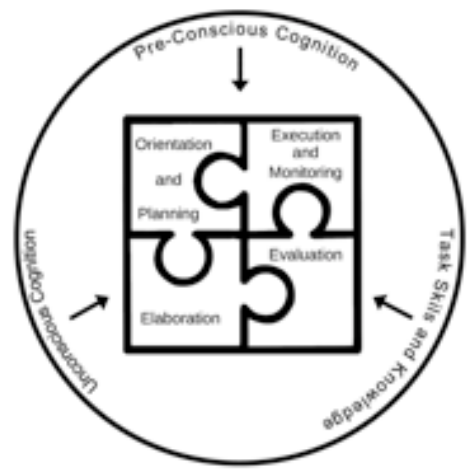

*Figure 1* Author's Visual Representation of Metacognition

Through researching metacognition and working through my inquiry project, I have been struck by how the metacognitive process and the inquiry process reflect each other. Scanning, focusing, and developing a hunch reflects orientation and planning; learning and taking action reflects execution and monitoring; checking reflects evaluation; and continuing/repeating the process with a new context and new goal reflects elaboration. Conscious of the

*Figure 2* Spiral of Inquiry Model (Kaser & Halbert, 2014)

connection between metacognition and inquiry, I have structured this paper to reflect my metacognitive journey through the DLC3 program. I have included field notes to share moments of my own metacognitive realization and development.

## Part 1: Orientation and Planning

### 1.1 Introduction and Inquiry Project Description

I had my first exposure to computer programming in grade 4. In the school computer lab, I would insert the 5 ¼" Turtle Graphics floppy disk into one of our Commodore 64s, and code drawings and simple programs. I consider this to be one of the most powerful and formative educational experiences of my life.

I didn't know it at the time, or for a long time after, that what I was learning was metacognition. Programming a triangle to move around the screen, I learned to plan ahead, consider the steps of an activity, put them in order, and implement them. I learned to assess whether my thoughts actions resulted in the intended outcome, and how to adjust and correct when they didn't. I learned how to start with a simple idea, and build on it to develop more complex ideas. I learned to express my ideas and my thinking in clear, step by step language, making it possible to improve my understanding of my own thoughts.

> **Field Note: Pre-Conscious Cognition:** Learning to code was an extremely powerful learning experience for me as a child. If asked, I probably could not have told you then that I was doing all the things I was doing. My thinking process was deeply enriched through this experience, but conscious awareness of this was a later step in my journey. This childhood experience was my pre-conscious cognition. Could it have been made richer by making it conscious?

Now, as an educator, I want to pass the same interesting and valuable experiences on to my students. Wanting to expand my knowledge of the benefits of coding beyond my own anecdotal experiences, I decided to engage in a qualitative inquiry into the topic. I wanted to explore the effects of learning to code on the development of metacognitive skills, and how I could design lessons and complementary activities to best support students in building these skills.

The tools available for students to learn to code have advanced beyond the little green triangle I called a turtle back in grade 4. A program called Scratch enables students to create computer programs using a block- and graphics-based interface. This enables students to use the same thinking skills as when creating computer programs using a programming language, without having to learn the syntax, essentially a whole new language.

In this project, I used Scratch to explore coding as a learning tool in my classroom. My inquiry involved students learning to code using Scratch, and complementing their coding lessons with planning and reflection activities designed with the intent of supporting metacognitive development. Academic research (Papert, 1971a, 1971b), expert opinion (Resnick, 2012), and my own personal experiences support the richness of coding as a tool to help students learn a variety of important skills, including meaningful experimentation and tinkering, computational thinking (which involves perceiving and understanding a larger problem and then breaking it into simpler parts), debugging and problem-solving, communication, metacognition, and persistence and perseverance (Martinez & Stager, 2013; Resnick, 2013). I chose to focus specifically on the skill of metacognition, defined as the awareness of one's own thinking, and the ability to describe and regulate it (Dinsmore, Alexander, & Loughlin, 2008; Miller, Kessel, & Flavell, 1970). Questionnaires and samples of students' work were used as research data to analyze and build an understanding of how their metacognitive skills improved throughout the unit, and what contributed to metacognitive growth.

## 1.2 Inquiry Purpose

Metacognition has been identified as an important contributor to student success in school (Flavell, 1979; Pintrich 2002). My purpose in this research was to foster student achievement through development of metacognitive ability, to improve my own understanding of student metacognition, and to identify effective and useful curricular components and methods that can be used by both myself and other educators in the future.

### 1.2.1 Inquiry Question

My inquiry question was, using coding as a learning activity, can I effectively foster the development of metacognition in my students? I looked at how to assess student metacognition, how to design and implement learning activities to support students in developing metacognitive awareness, how individual and group reflective activities could promote and demonstrate metacognition, and how student metacognitive ability changed over the course of the inquiry.

## 1.3 Key Concepts

### 1.3.1 Metacognition

Metacognition refers to an awareness of one's own thinking and the ability to describe it (Dinsmore et al., 2008; Miller et al., 1970). Metacognition has been shown to be an important skill for children's success in school (Flavell, 1979; Pintrich, 2002). Solomon and Papert (1976) suggest coding can be an effective tool for the development of metacognition, through a process of planning, modelling, thinking, coding, and reflecting. Making this process explicit can encourage metacognition by forcing students to break their thinking down into steps and become aware of each step.

### 1.3.2 Coding to learn

"Coding to learn" refers to the rich academic context created by learning to code computer programs. Learning coding is not about a single end goal of being able to program a computer; it is a process through which children (and adults) can learn numerous other skills and competencies. Through coding, students learn mathematical and computational thinking (which requires breaking down complex problems and ideas into simpler parts), problem-solving strategies, design processes and thinking, metacognition, communication skills, self-expression, empowerment, persistence, and perseverance (Resnick, 2012, 2013; Papert 1971a, 1971b).

### 1.3.3 Constructionism

Constructionism, rooted in constructivist theory, was developed by Seymour Papert. Constructivism is the theory that learning is an active process of making sense of the world, which happens best when participating in authentic, hands on experiences. Constructionism, as an area of constructivism, focuses on how the act of making something shareable creates a unique learning opportunity. The making process fosters metacognition, as makers of shareable objects (whether physical or virtual) have a unique understanding of the steps involved in a process (Martinez & Stager, 2013).

## 1.4 Timeline

A general timeline of my progress towards the completion of my coursework and graduating project is outlined in Appendix 1. The following timeline focuses specifically on the planning, preparation, and implementation of my graduating inquiry project.

*Table 1.* Graduating Project Timeline

| | |
|---|---|
| July 2015 | - Draft initial inquiry proposal<br>- Identify and clarify key terms related to inquiry |
| January – April 2016 | - Identify and analyze ethical issues related to inquiry project<br>- Implement test/practice coding program in classroom; informal observations and analysis of program concerns and possibilities |
| March – April 2016 | - Use informal observations from test/practice coding program to develop curricular resources for use during my formal graduating inquiry project |
| July – August 2016 | - Update graduating project proposal<br>- Begin literature review of key terms, concepts, and research related to inquiry |
| January 2017 | - Get parental permission for classroom use of Scratch online programming |
| February 2017 | - Conduct pre-assessment questionnaires and think-aloud assessments |
| February – April 2017 | - Engage in Scratch coding and metacognition unit in classroom |
| April – May 2017 | - Conduct post-assessment questionnaires and think-aloud assessments<br>- Analyze data |

**Field Note: Unconscious Cognition**

I previously worked with some colleagues who did their master's degree almost immediately after graduating from their bachelor of education program. At the time, I knew I wasn't ready for this. Teaching was still too much of a conscious cognitive effort for me to be ready to formally inquire into my teaching process in the way I have through this program.

Armstrong (1989) explains unconscious (or automatic) cognition as that which we can do without awareness or conscious thought. To feel ready for this formal inquiry I had to develop the task skills and knowledge of teaching to the point that I could do many of them automatically (or at least with much less conscious effort). This left space in my conscious mind for all the new skills I needed to learn and apply in order to engage in this inquiry process.

Much of this journey occurred before starting my master's degree. It involved gaining teaching experience to build comfort in the classroom setting. It involved building professional relationships with students – getting to know my students better, and building the skills to be responsive to students' classroom needs.

This journey continued after starting my master's degree. In my classroom, I practiced teaching coding, and worked through possible ways to support and assess learning. Through course work, I planned and practiced possible teaching and research methods to carry out in the classroom. Through participation in and leadership of seminars, I practiced engaging in and reporting on inquiry.

I see unconscious cognition as an extension of task skills and understanding. I remember discussing what was called 'unconscious competence' in of my BEd classes. It was described as being so capable of a task that one could complete it without thinking. Building some of my skills to that level was an important part of my preparation to begin and conduct my formal master's inquiry project.

## 1.5 Literature Review

### 1.5.1 Introduction

In this project, I explored the use of coding as a learning tool in my classroom. Academic research (Papert, 1971a, 1971b), expert opinion (Resnick, 2012), and my own personal experiences support the richness of coding as a tool to help students learn a variety of important skills, including meaningful experimentation and tinkering, computational thinking, debugging and problem-solving, communication, metacognition, and persistence and perseverance (Martinez & Stager, 2013; Resnick, 2013). I chose to focus specifically on how learning to code supported the development of metacognitive skills in my students.

With this primary goal, several areas of existing research were relevant to explore prior to beginning my own inquiry. To begin, it was important to have a clear understanding of metacognition and previous research into metacognitive development, particularly in children. Next, it was relevant to explore characteristics of the coding learning environment that may or may not contribute to metacognitive learning. Understanding this included an exploration of learning theory, particularly constructivist and constructionist theories, as well as previous research into the implementation of coding as a learning tool.

### 1.5.2 Metacognition

#### *Defining Metacognition*

The concept of metacognition appears to originate in 1970s research by Flavell (Flavell, 1979; Miller, Kessel, & Flavell, 1970). Miller et al. (1970) explore children's recursive thinking, or 'thinking about thinking'. While this study provides a starting point for considering children's ability to reflect on thinking, it does not fully develop the idea of metacognition, as the authors primarily consider how children think about others' thinking, rather than reflecting on their own thinking.

Flavell (1979) develops the idea of metacognition in much more detail. He identifies four interacting dimensions of metacognition. Metacognitive knowledge refers to what an individual knows about themselves and others that has to do with cognitive tasks, goals, actions or experiences. This includes: knowledge/beliefs about individual people, and truths about cognition; understanding of a cognitive task, and beliefs about how the information available about a task influences task completion; knowledge regarding what strategies are likely to be useful in what situations. According to Flavell (1979), metacognitive

> **Field Note: Task Skills and Knowledge**
>
> In one of our class seminars, the seminar leaders asked the question, "Would somebody else be able to do your inquiry?" This question led me to ask myself what task skills and knowledge I need/needed in order to conduct my inquiry project. My first reaction to the seminar question was that I'm not sure just anybody could, since they would not necessarily have the skills and knowledge to do the same things I am doing. I was challenged in this assertion by one of my colleagues. I appreciated this challenge, which led me to reflect further. My new conclusion was that somebody without the same set of skills and knowledge could conduct a similar inquiry, but it would look a little bit different. So I changed my question to myself to which task skills *I* used in the process of my inquiry. What task skills made this inquiry uniquely mine, and possible for me?
>
> For this inquiry to form the way it did, *I* needed to have an understanding of coding and of metacognition; I needed to have the skills to teach both of these things; I needed to understand and be able to apply the inquiry process; I needed creative skills to create my own assessment tools for metacognition; I needed to understand assessment; I needed research skills; .... I feel I could continue this list for a long time.
>
> My journey of building these skills was a long one, which took place through elementary school coding experiences, high school computer science and language arts classes, university student government leadership, undergraduate research and writing, and graduate classes in preparation for my inquiry. The more I reflect on it, the more I realize how long, complex, and unique my learning journey was. I know my students are on their own unique learning journey, with different levels of preparedness for what I hope they will learn through this inquiry. I need to be aware of this at all times, in order to be the best guide and supporter I can possibly be.

knowledge can be conscious or unconscious. I feel this causes some lack of clarity if metacognition is to be understood as thinking about thinking, as conscious awareness seems to be an important component of metacognition. However, Flavell (1979) somewhat clarifies this point by stating that metacognitive knowledge can give rise to conscious experience. Seemingly, cognitive knowledge, which may sometimes be unconscious, is the required prerequisite for conscious metacognitive thought.

Metacognitive experiences, Flavell's (1979) second dimension of metacognition, are conscious cognitive or affective experiences either regarding or in response to cognitive efforts. The experiences guide decision making about cognitive tasks, and also contribute to the development of metacognitive knowledge (reflecting constructivist and constructionist learning theories, to be discussed later in this literature review). His third dimension, metacognitive goals refers to the objectives of a cognitive task. The fourth dimension, metacognitive strategies refers to cognitive behaviours used to achieve the metacognitive goals. While cognitive strategies are used to make cognitive progress, *meta*cognitive strategies are differentiated in that they are used to monitor cognitive progress. What appears to emerge is a definition of metacognition which is differentiated from cognition by two factors: it is conscious and intentional, and it is a process of monitoring (as opposed to just making) cognitive progress.

Brown and Deloache (1978) also support the idea that conscious monitoring is an important part of metacognition by identifying a set of basic metacognitive skills used for "*coordinating* and *controlling* deliberate attempts to learn and solve problems" (p. 15). The skills they outline, and particularly the use of words like controlling and deliberate clearly point to conscious, intentional thought. Brown (1984) further defends this focus on consciousness. Drawing on Piagetian constructivist theory, Brown notes that all cognitive experiences combine to build a schema of cognition. If all experiences affect one's thinking, it isn't sufficient to say that metacognition is simply about cognitive experiences that (consciously or unconsciously) affect future cognitive experiences. Rather, Brown (1984) makes an important and supported distinction, suggesting metacognition is about how we consciously monitor our thinking processes in order to think more efficiently and effectively. Armstrong (1989), distinguishes between automatic processing and controlled processing, and talks about the importance of controlled processing to guide cognition when automatic processing is insufficient.

Thomas (1984) looks to the etymology of the prefix meta to identify and support a definition of metacognition. He finds some support in meanings of meta that arise from an apparent misunderstanding of the term metaphysics. Here, meta is seen to mean transcending, above, or encompassing. This definition of meta supports the idea that metacognition is a step up from cognition. Thomas (1984) notes that in his review of educational literature, meta is popularly defined as "knowledge about" or "an analysis of", supporting the idea that metacognition would be about conscious analysis and regulation of thinking. In early writing on metacognition, there clearly emerges a trend that consciousness and intention are perceived as defining characteristics of metacognition.

More recently, Dinsmore, Alexander, and Loughlin (2008) sought to clarify the definition of metacognition through an extensive review of literature referring to the term. Reading 123 educational studies where metacognition was a key word, they noted a lack of agreement regarding a definition, and often a lack of clarity or statement of a definition in specific studies. However, the trend they noticed was that metacognition tended to be defined by researchers as the mental efforts of individuals to consciously monitor and respond to their thoughts. In my own research, it will be important to clearly define metacognition, along lines that fit within the existing academic literature. This points me to a definition that will include awareness, intention, and self-regulation of cognition.

### *Research into Metacognitive Development*

In the research into metacognitive development in children and adults, I found two patterns that emerged. Miller et al. (1970) found that older children demonstrated a better awareness of thinking. Flavell (1979) cites two of his own unpublished studies demonstrating that younger children appear less aware of their own cognition. Flavell, Green, and Flavell (2000) found adults and older children were better able to describe their thinking. They thoroughly analyze why by suggesting several possible reasons; they justify selecting the conclusion that metacognitive abilities develop with age by demonstrating how the study was effectively designed to eliminate researcher/participant power imbalances, and it is unlikely that children have exceptional cognitive abilities adults do not have. Likewise, Flavell, Green, Flavell, and Lin (1979) found more developed cognitive awareness in older children. Armstrong (1989) found older children were better able to think ahead and prevent mistakes, as well as reflect on mistakes to use them as learning opportunities. The first pattern that emerged was that researchers clearly found that metacognitive ability appears to develop with age. In each of these studies, the researchers inferred this meant metacognition was a developable and teachable skill.

The second pattern that I found in this research was that the studies into metacognitive development did not appear to fully support this inference with baseline or control data. While comparing metacognitive abilities across ages certainly supports that this skill develops over time, it does not suggest whether or not, or how, metacognitive skills can be effectively taught. In each of these studies, children of different ages were compared, but never the same child at different ages, or the same child before and after a learning activity. Armstrong (1989) specifically states one goal of her study is to assess how training and prompting in metacognitive strategies supports metacognitive development. Students were given training on a coding based learning activity, and received protocol sheets (essentially step by step instruction sheets) designed to mimic problem-solving and metacognitive skills. However, the study does not include a comparison group that did not receive the training and sheets. As such, the study does not demonstrate how instruction contributed to students' abilities. With the instruction sheets given at every step of the study, it is also unclear how much students were internalizing or consciously using the steps outlined. This demonstrates to me the importance of collecting baseline data in some way to assess not only where my students are at, but what sort of progress they make over time.

There were some studies that conducted pre-testing and compared groups to examine child development over time, or through a learning program. Clements and Gullo (1984) pre-tested children and randomly assigned them into two groups. They found that the children who participated in a computer coding program significantly improved their metacognitive and problem-solving abilities. Hussain, Lindh, and Shukur (2006) likewise had pre- and post-testing, and had control groups in their research design. They found an improvement in mathematical and reasoning abilities (related to metacognition) following an educational program focused on robotics and programming. It is interesting that both of these studies are specifically in the realm of education. It is possible that the other research studies examined were more focused on psychological development than on the educational significance of metacognition. Both Clements and Gullo's (1984) study and Hussain et al.'s (2006) study investigate educational programs specifically focused on using coding to teach students. Papert

(1971a, 1971b, 1980) strongly advocated for the use of coding as a learning tool for children. He believed it creates a unique learning environment that fosters the development of thinking skills. This will be further explored later in this literature review.

### *Assessing and Measuring Metacognition*

In order to effectively understand how student metacognition has changed through the course of my inquiry unit, it will be necessary to effectively assess student metacognition. In their review of literature, Akturk and Sahin (2011) identify three categories of metacognitive assessment. Probable assessment occurs before engagement in a cognitive task; simultaneous assessment occurs while a metacognitive task is in progress; retrospective occurs following a cognitive task. Veenman and Alexander (2011) identify two categories of metacognitive assessment. Online assessment refers to assessment that occurs while a metacognitive task is in process. Offline assessment, which reflects a combination of Akturk and Sahin's (2011) probable and simultaneous assessment, occurs before or after the cognitive task.

In an extensive review of literature on measuring metacognition in children ages 4-16, Gascoine, Higgins, and Wall (2016) found that offline assessments, and specifically questionnaires, surveys, and self-report tests, are by far the most common metacognitive assessment practice. There is research both in support of and critical of this (Gascoine et al., 2016); however, it was difficult to locate or access full-texts of primary resources. Baker and Cerro (2000), as cited in Scott (2008) indicate that students completing questionnaires may misunderstand questions. Lin and Sandmann (2003) and Muis et al., 2007, as cited in Neuenhaus, Artelt, Lingel, and Schneider (2011) report that offline assessments may fail to predict academic achievement or actual metacognitive awareness. Leopold and Leutner (2002), as cited in Neuenhaus et al. (2011), critique that questionnaires rely on respondents' awareness and recognition of strategies, rather than on actual knowledge and strategy use. However, as awareness is an important aspect of metacognition (Brown & DeLoache, 1978; Flavell, 1979), it may be relevant to assess awareness and recognition of strategies.

The primary research I located did not provide a conclusive picture of the validity of questionnaire assessments. Jacobse and Harkamp (2012) compared results of four different types of metacognitive assessment with the same set of students – think-aloud assessment, a self-report questionnaire, a content knowledge/performance test, and a procedural test they created where students completed a set of procedures related to metacognition. They found results of the think-aloud test correlated with their procedural test and did not correlate with the questionnaire. They concluded that procedural tests, being much less time consuming than think-aloud protocols can give significant assessment data about metacognition. Schellings, van Hout-Wolters, Veenman, and Meijer (2013) similarly compared results from a questionnaire and a think-aloud assessment. They found no correlation between the think-aloud assessment and parts of the questionnaire (such as questions focused on orientation and planning); however, they found an overall correlation present between the two assessments. O'Neil and Abedi (1996) compared results of think-aloud protocols to achievement on specific tasks. They found significant correlation, suggesting the validity of think-aloud assessment, and therefore relevance of using think-aloud assessments to validate questionnaires. In addition to Schellings et al.'s (2013) findings, Gascoine et al. (2016) also refer to research supporting a correlation between questionnaires and think-aloud assessments. Akturk and Sahin report further support for the use of questionnaires, indicating questionnaires are easy and unobtrusive to administer, and they provide quick and objective evaluation.

As indicated above, think aloud assessments have demonstrated validity (O'Neil & Abedi, 1996). They are also able to provide clear and specific information about a student's thinking, without the need for observer interpretation (Veenman & Alexander, 2011). However, there were also criticisms of think-aloud assessments. They can be time consuming and interfere with the learning process (Akturk & Sahin, 2011; Veenman & Alexander, 2011); they are necessarily domain dependent (O'Neil & Abedi, 1996) and therefore cannot report on general metacognitive ability and awareness; younger students or those new a cognitive task may also be so focused on the task that they are unable to verbalize their thought process effectively (Veenman & Alexander, 2011).

I found a combination of literature supporting and critiquing each different type of assessment. It will be important to consider the benefits and drawbacks of each form of assessment when deciding how to assess my students' metacognition for my inquiry.

### 1.5.3 Learning Theories

Learning theories will be discussed in further detail in the curriculum analysis section of this paper. Here I will give a short outline of the learning theories that support the use of coding as a learning activity in the classroom.

#### *Constructivism*

Constructivist learning theory is rooted in the works of Jean Piaget and Lev Vygotsky (Weegar & Pacis, 2012). Essentially constructivism is the believe that learning is a process of constructing knowledge through the combination of past and present experiences (Martinez & Stager, 2013). New experiences are combined with previous knowledge to create an understanding of the world, (Martinez & Stager, 2013; Rummel, 2008, as cited in Weegar & Pacis, 2012). Piaget's "cognitive constructivism" (Chambliss, 1996, as cited in Weegar & Pacis,

2012) focuses on the cognitive processes of construction of knowledge within the individual through interaction with their environment (Piaget & Inhelder, 1966). Vygotsky's "social constructivism" (Gulati, 2008, as cited in Weegar & Pacis, 2012) placer greater importance on interpersonal interaction, looking at how external, interpersonal events are internalized with time and repetition (Vygotsky, 1978).

#### *Constructionism*

Constructionism, a term coined by Papert (Martinez & Stager, 2013), fits within constructivism. It specifically refers to knowledge that is constructed through the process of making something tangible. This learning process can be particularly powerful, as the personal connection to the process as well as product can lead to significant engagement, reflection, and connections (Martinez & Stager, 2013; Papert, 1980).

### 1.5.4 Coding and Metacognition

Papert (1971b, 1991) asserts that coding is an effective way of learning thinking skills, as the process of coding forces the programmer to break down the processes of what they do and how they think. He provides case study and anecdotal evidence demonstrating the complex thinking process even young children go through in the creation of a program. The experimental design leading to these observations is not clear. Other research provides an inconsistent set of evidence regarding whether or not coding can lead to the development of thinking skills.

Littlefield, Delclos, Bransford, Clayton, and Franks (1989) criticized previous research in the field for lacking clear detail about teaching methods and processes (similar to my criticism of Papert, 1971b and 1991). Their study specifically focused on comparing two different teaching methods for students to learn coding: explicit teaching of coding language and processes; and a more open, discovery method, where students explored and figured things out on their own.

They found that explicit teaching was necessary in order or students to learn more than a beginner level of coding language and skills. Littlefield et al. (1989) concluded that their findings could be extended to students' problem-solving skills—that, like coding language and processes, problem-solving skills required explicit teaching to be learned effectively. I am not sure that this conclusion is fully defensible. On one hand, their research was well designed to control for teaching method, providing strong evidence in support of explicit teaching. On the other hand, they measured coding ability rather than problem-solving ability, and it is possible that the teaching/learning method impacts problem-solving skill development differently than coding ability (for example, it is possible problem-solving skills are better learned through independent discovery, even though coding skill develops more effectively through explicit instruction). Additionally, it is possible that time played a relevant role. The study looked at learning that occurred over five weeks (Littlefield et al., 1989). It is possible that ultimately the independent discovery learning would have a slower start to learning, and might have yielded significantly better results over a longer time period.

Missiuna et al. (1987) studied the impact of the "Thinking with LOGO" curriculum, implemented in the Calgary School Board. This curriculum was focused on teaching generalizable thinking and problem-solving skills through learning to code. They found no significant difference in pre- and post-test measures of students' problem-solving and thinking skills. One explanation they suggest for this was the short period of time for implementation – perhaps with more time to implement the program, different results would have emerged (Missiuna et al., 1987). Taking the idea of timeline further, in addition to learning for a short period of time in the year of study, learners engaged in only a short portion of the program. The "Thinking with LOGO" curriculum was designed for implementation with students from grades

1 to 6. The study looked at students in grades 3 and 5, who engaged in only one portion of the program (Missiuna et al., 1987). It is possible results would be significantly different if students began the program in grade 1, and continued sequentially throughout the program, building skills from previous years. I also found it interesting that although they concluded their results were not statistically significant, they did find improvement in problem-solving skills for both grade groups. This improvement was larger for the grade 5 group (Missiuna et al., 1987). This suggests the possibility that older students are more prepared for learning problem-solving skills and are able to build these skills more quickly.

Lindh and Holgersson's (2005) study took place over 12 months, providing information about the effect of an extended time-period for learning. Students were tested for mathematical and logical skills before and after using Lego programmable construction kits. Their two different analyses showed different results. Comparing pre- and post-tests suggested no significant improvement over students who did not participate in the learning program. However, looking at correlations between participation and development of problem-solving skills, a significant correlation was identified. The authors concluded that their data were promising regarding the impacts of programming on mathematical and logic skills, but also inconclusive (Lindh & Holgersson, 2005).

Linn (1985) studied how students in a coding program progressed along an identified chain of problem-solving skills. She found that children in all classes progressed in their problem-solving skills throughout the study. However, students in classes with what she identified as exemplary teaching advanced more significantly in their problem-solving skills. Aspects of exemplary teaching identified in the study included explicit teaching of both coding and problem-solving skills, well designed assignments, debugging time, and giving students planning time before using computers. In addition to improved development of problem-solving skills, classes with exemplary teaching had less difference between more advanced and struggling students within a class, and a lower correlation between access to computers at home and achievement in class. While the study gives strong evidence for the value of explicit and well-designed teaching (agreeing with Littlefield et al., 1989), it has one flaw in that it is not clear how the problem-solving skills of students in the study were measured.

White and Frederiksen (1998) also looked explicit teaching, through examining students engaged in a physics curriculum while being explicitly taught and guided through metacognitive processes. They found the teaching of metacognition improved students' abilities to engage meaningfully in inquiry processes. While they do not specifically look at computer programming, they do provide strong evidence for the value of learning metacognitive skills.

#### 1.5.5 Next Steps

##### *How my Inquiry was Guided by Past Research*

The research examined offered helpful guidance and direction for my own research. A clear definition of metacognition as conscious cognition led me to focus on students' conscious awareness of their thinking skills. Understanding considerations in the assessment and measurement of metacognition contributed to the designing of my assessment procedures (explained in further detail in the methodology section of this paper). Constructivist and constructionist learning theory contributed to an ethical defense of my inquiry as an effective learning activity for my students (explained in further detail in the curriculum analysis section of this paper). The inconsistency of results of previous research into coding as a learning activity to promote development of thinking skills suggests further research into this is relevant. Additionally, most of this research focused on problem-solving skills (e.g. Linn, 1985; Missiuna et al., 1987) or domain specific skills such as mathematics (e.g. Lindh & Holgersson, 2005). There appears to be value in looking specifically at metacognitive skills, as defined above.

#### *How My Inquiry Will Contribute to the Academic Literature*

Considering the incomplete picture that emerged from my review of literature, my inquiry was developed to contribute to a better understanding of the benefits of elementary school students learning to code. The inquiry contributes to an understanding of whether learning to code specifically supports metacognitive skill development. I also contribute to an understanding of how pairing computer programming education with lessons about metacognition can support metacognitive development.

### 1.6 Curriculum Analysis

> "…children learn by doing and by thinking about what they do. And so the fundamental ingredients of educational innovation must be better things to do and better ways to think about oneself doing these things." (Papert, 1971b, p. 1-1)

The learning activities engaged in for this study contain some obvious explicit links to curricula. However, the more exciting part of what happens when students learn to code is what is not explicitly stated. Resnick (2012, 2013) discusses what emerges as implicit curriculum when students learn to code. Understood within constructivist (Piaget & Inhelder, 1966; Vygotsky, 1978) and constructionist (Papert, 1980, 1971b; Papert & Harel, 1991; Turkle & Papert, 1991) perspectives, learning to code emerges as a unique and powerful opportunity for learning thinking skills while empowering students and encouraging social change.

### 1.6.1 Explicit Curriculum: Learning to Code

BC's New Curriculum consists of core competencies (habits, processes, and abilities that apply across curricular areas), big ideas (major concepts within each curricular area and grade level), curricular competencies (habits, processes and abilities either unique to or especially highlighted within specific curricular areas), and curricular content (specific topics and knowledge to be learned in each curricular area for each grade level) (British Columbia Ministry of Education [BCME], 2016f). Starting at the most concrete of these, I will look at curricular content for elementary school grades. Coding fits within the Applied Design, Skills, and Technologies (ADST) curricular area. While the ADST curriculum does not contain any specific curricular content for grades K-5 (instead learners are expected to apply in other areas the ADST competencies for these grades), the grades 6 and 7 ADST content explicitly includes visual programming, which includes Scratch programming (BCME, 2016a). The grades 6 and 7 ADST content also includes computational thinking, troubleshooting problems on computers, internet safety, digital citizenship, simple computer-aided drawing, sound editing, and programming for robotics (BCME, 2016a). Coding supports learning of this content and in these areas (Resnick, 2012, 2013). This is the explicit curriculum of what students are learning when they learn to code. It's already exciting that an activity this engaging for students supports learning this wide base of skills and knowledge. However, it gets much more exciting when one looks at implicit curriculum of learning to code. While students learn to code, they are learning much more than just this explicit skill: "they are not just learning to code, they are coding to learn" (Resnick, 2012).

### 1.6.2 Implicit Curriculum: Coding to Learn

Constructivist learning theory states that knowledge must be constructed in the mind of the individual. An individual combines their observations of the current experience with what they already know to build a model or schema of the world (Martinez & Stager, 2013; Weegar & Pacis, 2012). While constructivism focuses on the internal construction of knowledge in all situations, constructionism focuses more specifically on knowledge that is constructed through the process of making something tangible or shareable (Martinez & Stager, 2013). As far as coding is concerned, the coder is the creator or maker of a computer program. Coding holds a special place within constructionism, since the process of making is both abstract and concrete at the same time—the process of building involves teaching a computer what to do (Papert, 1980; Papert & Harel, 1991).

This change of usual relationships is what makes coding such a powerful and unique learning opportunity. Vygotsky (1978) explains learning as a process of internalizing repeated developmental events. Humans use tools, directed outward, to interact with and control our environment; we use signs, directed inward, to make sense of and control our inner world. Language is an example of a sign, used to make sense of and organize our thinking (Vygotsky, 1978). We must therefore require the appropriate language or internal signs in order to control our own thinking. However, our learning environments do not include many opportunities for developing this sort of awareness. Many uses of computers in education involve the computer either teaching the student or telling the student what to do. In creating a computer program, this relationship is reversed: the student becomes the teacher, teaching the computer what to do and how to think. In the process of teaching the computer what to do and how to think, the student must explore how they themselves do what they do, and how they think what they think (Papert, 1980).

In order to effectively program the computer, the student must then articulate this thinking, for example by choosing the right commands or scripts to make the program do what they want. Papert (1980) implies that the ability and practice of articulating one's own thinking will lead to an improvement of it. This is supported by Vygotsky's (1978) explanation of tools and signs. The script (or command) on the computer becomes the tool with which the student influences the environment (the program); the effectiveness (or ineffectiveness) of this script/tool influences the internalization of the child's understanding of thinking. Through programming, children get an opportunity for repeated practice of making their thinking conscious, while testing and refining their thinking processes. Since metacognition involves the ability to be aware of, describe, and regulate one's own thinking (Akturk & Sahin, 2011; Brown, 1984; Flavell, 1979), coding can be understood as a unique opportunity to develop and practice metacognitive skills.

### 1.6.3 BC's New Curriculum

BC's new curriculum recognizes the value of constructivist and constructionist approaches. While it is important to note that constructivism and constructionism are not a curriculum (they are learning theories) (Martinez & Stager, 2013), they offer important direction for curriculum and important insights into the implicit curriculum of coding to learn. BC curriculum documents assert that "Deeper learning is better achieved through "doing" than through passive listening or reading" (BCME, 2016e). This assertion is validated through the construction of a curriculum that prioritizes student development of competencies through engagement in authentic experiences oriented around curricular content. While metacognition is not explicitly mentioned, many examples of metacognitive skills can be found throughout the core and curricular competencies. A small number of selected examples of this are in table 3, organized into metacognitive skill categories of orientation and planning, execution and monitoring, evaluation, and elaboration.

*Table 2* Examples of metacognitive skills in BC curricular and core competencies.

| **Orientation and Planning skills** | |
|---|---|
| **Curricular Area** | **Curricular Objective OR "I" Statement** |
| ADST Grade 6 | Students will be able to screen ideas against criteria and constraints. |
| ADST Grade 6 | Students will be able to make a plan for production that includes key stages, and carry it out, making changes as needed. |
| Critical Thinking Core Competency | I can consider more than one way to proceed and make choices based on my reasoning and what I am trying to do. |
| **Execution and Monitoring Skills** | |
| **Curricular Area** | **Curricular Objective or "I" Statement** |
| ADST Grade 6 | Students will be able to test versions of a prototype, make changes, troubleshoot, and test again. |
| Critical Thinking Core Competency | I can examine my thinking, seek feedback, reassess my work, and adjust. |
| Personal Awareness and Responsibility Core Competency | I can tell when I am becoming angry, upset, or frustrated, and I have strategies to calm myself. |
| **Evaluation Skills** | |
| **Curricular Area** | **Curricular Objective or "I" Statement** |
| ADST Grade 6 | Students will be able to evaluate their product against their criteria. |
| Social Responsibility Core Competency | I can clarify problems, consider alternatives, and evaluate strategies. |
| Communication Core Competency | I can recount simple experiences and activities, and tell something I learned. |
| **Elaboration Skills** | |
| **Curricular Area** | **Curricular Objective or "I" Statement** |

| | |
|---|---|
| Creative Thinking Core Competency | I use my experiences with various steps and attempts to direct my future work. |
| Critical Thinking Core Competency | I can describe my thinking and how it is changing. |
| ADST Grade 6 | Students will be able to identify new design issues. |

(Sources - BCME, 2016a, 2016b, 2016c, 2016d, 2016g, 2016h)

The BCME (2016e) asserts a desire for a transformed curriculum with learner-centred personalized learning, and opportunities for learning that did not previously exist. Coding presents a learner-centred environment, where it is both accessible and challenging to students at all levels, and with multiple learning styles (Papert, 1980; Turkle & Papert, 1991). Beginner programmers see immediate results from their creations; more advanced programmers are challenged with the almost endless possibilities of what can be programmed (Papert, 1980). Learners can navigate the programming environment and build their coding and thinking skills in multiple ways (Turkle & Papert, 1991).

Puentedura (2014) identifies four ways in which technology is typically used in educational settings: substitution, in which the technology replaces old technology or tools with no functional change; augmentation, in which the technology replaces old technology or tools with some functional change; modification, in which the technology creates the opportunity for significant redesigning of tasks; and redefinition, where the technology makes possible new tasks and learning that were previously inconceivable. The BCME has encouraged a real transformation of learning by including coding in the ne BC curriculum, validating this unique opportunity for authentically developing and applying thinking skills. I have been really excited to explore this unique way for my students to build their metacognitive skills.

## Part 2: Execution and Monitoring

**Field Note: Orientation and Planning**

So, this is where my Master of Education degree starts. Although, maybe it starts a little bit before that. I honestly hadn't planned on doing my master's degree for at least a few more years, but in Spring 2015 I went to an information session about the DLC program, and I'd say that's where I started this portion of my journey. I knew immediately that I wanted to be a part of this cohort, and I wanted to focus on coding and metacognition. As I said earlier, I knew this was a rich educational experience for me when I was an elementary school student. I have been wanting to pass on the same experience to my students for a while. Although I had approached the subject before with my students, I knew I wanted to make a more focused effort to teach my students about metacognition through coding. It was at this session that I began to develop a conscious idea of how my graduate inquiry would look, and how I would get there.

My orientation and planning continued throughout the following year. Through course work and informal inquiry in my classroom I oriented myself to the essential question I wanted to answer, and developed a plan for getting to that answer. I found myself answering many questions along the way, some easy and some challenging.

What precisely is metacognition? How does one measure metacognition? How much should I focus on explicit teaching of metacognition? How much should I let the learning activity (coding) speak for itself? (Like inquiry, metacognition is not a unidirectional process) – How much was I explicitly taught metacognition when I was a child? Does my answer to that question lead to the same conclusions as research in the area of teaching metacognition? Okay, research says explicit teaching is necessary (Linn, 1985; Littlefield et al., 1989) – how does one teach metacognition? How should I sequence or combine learning activities oriented towards metacognition with the task skills necessary for coding? How much should I direct student learning and how much should I leave open for students to direct their own inquiry? What research approaches and methodology will be most meaningful for my inquiry? How do my beliefs about curriculum and human development contribute to structuring my teaching and research practice? How will I know if students' metacognitive abilities changed throughout the unit? How much should I focus on summative vs. formative assessment? How does my inquiry fit into the new BC curriculum? How do I approach this inquiry ethically? …?

And I guess here is where I was ready to start. I went through my metacognitive checklist: I knew what I already knew; I knew what I wanted to find out; I knew how I thought I could do that; I knew where to start. Looking at my inquiry as a metacognitive exercise, I knew I was ready to move on to the next step, and begin implementation.

### 2.1 Research Setting

This inquiry was completed in a grade 5/6 class of 27 students in Richmond, BC. The class was mixed in terms of gender, and diverse in terms of academic ability. Many of the students speak a language other than English at home. The in-class unit for this study took place over 2 months, from March to April 2017.

### 2.2 Methodology

A mixed methods approach was used for this study. Student metacognition and emerging thinking skills were measured and observed using a questionnaire, think-aloud protocols, classroom observations, and a combination of planning and reflection of activities. Before starting the coding and metacognition unit, students were given a pre-assessment multiple choice and short answer questionnaire to look at their use of metacognitive strategies and their awareness of thinking skills. Students also recorded each other thinking aloud while engaged in a coding-related problem-solving activity. During the coding unit, students learned coding skills using Scratch online, and learned about metacognition through various classroom lessons and activities. Reflection responses and classroom assignments were collected, to look at how they demonstrated the use and emergence of metacognitive skills. More detail on how this unit was taught is contained in the curriculum analysis section of this paper. At the end of the unit, students were given a questionnaire with the same multiple choice questions and some different short answer questions. They also repeated the think-aloud assessment activity.

### 2.2.1 Assessment Methods

#### ***Questionnaire***

Although my literature review found literature critical of the validity of questionnaires for assessing metacognition (e.g. Gascoine et al., 2016; Schellings et al., 2013), there was also support for the use of questionnaires. Questionnaires can be easy to administer, and can be completed by students without disrupting classroom thinking or learning (Akturk & Sahin, 2011; Veenman & Alexander, 2011). Schellings et al. (2013) found that questionnaires showed significant validity for some parts of metacognition – their results showed higher validity for questions focused on execution and monitoring than for orientation. Questionnaires were also criticized for their reliance on students' awareness of strategy use, as opposed to actual strategy use (Leopold & Leutner, 2002, as cited in Neuenhaus et al., 2011); however, as awareness has been identified as a critical component of metacognition (Brown & DeLoache, 1978; Flavell, 1979), I felt it was relevant to measure students' awareness of their strategy use. My questionnaire design took into account this combination of criticism and support.

The questionnaire included items aimed specifically at three categories of metacognitive activities, based on Veenman and Beishuizen (2004), as cited in Schellings et al. (2013). The three categories considered were orientation and planning (referring to metacognitive activities that occur prior to beginning a task), execution and monitoring (referring to metacognitive activities that occur during completion of a task), and evaluation and elaboration (referring to metacognitive activities that occur after completing a task). For curricular relevance, and to focus on students' self-awareness, the specific items on the questionnaire were based on "I statements" from the BC Curriculum's Core Competencies. O'Neill and Abedi (1996) found that difficulty understanding questions may have negatively contributed to questionnaire validity. To counter this, I reworded the statements to make the language easier for students to understand, and also to focus on metacognitive skills. The questionnaire was given to students electronically, using google forms. To ensure confidentiality, students were given a number to use to identify themselves on the questionnaire.

Table 2 contains a list of the items developed. Appendix 2 shows how each questionnaire item was developed.

*Table 3.* Metacognitive Skills Inventory Questionnaire

**Part 1: Multiple Choice Items** (students responded with always, usually, sometimes, usually not, never, or not sure).

1) Before I start working on a problem, I think about similar problems I have solved before to help me decide what to do.
2) Before I start working on a problem, I make sure I understand what I need to know to solve it.
3) I know if a problem is going to be hard or easy for me.
4) Before I start a problem, I think ahead to try to figure out what parts I can do on my own, and what parts I will need help with.
5) I like to think about more than one way to solve a problem before I decide what to do.
6) Once I choose a strategy to solve a problem, I know why I chose it.
7) Once I choose a strategy to solve a problem, I can explain why I chose it.
8) Before I start a problem, I think about what order I will need to solve it in. (What to do first, second, etc.).

9) When I am working on a problem, I just start and see what comes out of my work.
10) I can tell you why I chose the strategy I chose.
11) I am willing to try out a thinking strategy, even if I am not sure whether or not it will work.
12) When somebody asks me a yes/no question about what I am thinking while working on a problem or reading a book, I can usually answer them.
13) When somebody asks me to describe my thinking when I am solving a problem, I can usually explain it clearly.
14) When I get or figure out new information, I check how it fits with what I thought before.
15) I know when what I'm doing isn't working.
16) When something I'm doing isn't working, I try to figure out why.
17) When something I'm doing isn't working, I erase it and try the same thing again.
18) When I'm working on a problem, I know when I need help.
19) I know when I'm getting frustrated with a problem.
20) When I'm getting frustrated with a problem, I think about ways to make myself feel better.
21) When I'm getting frustrated with a problem, I "freeze" or give up.
22) When I realize that what I'm doing isn't working, I go over how I decided what to do, and try to figure out where I made my first mistake.
23) I can tell when there is a mistake in my thinking, even though I don't always know why.
24) After solving a problem, I can explain how I did it.
25) After solving a problem, I can think of other situations where a similar solution might be helpful.
26) After doing a lesson or an assignment, I can tell you what changed about my knowledge and thinking from before the lesson or assignment.
27) When I get stuck, or when I don't succeed at a problem or at part of a problem, I think about what I need to learn to succeed next time.

**Part 2: Short Answer Questions**

Pre-assessment

1) Tell me something you have noticed about your own thinking.
2) Tell me something you wonder about your own thinking or about thinking in general.
3) Tell me something that has changed about your thinking since kindergarten.

Post-assessment

1) Tell me something you have noticed about your own thinking.
2) Tell me something you wonder about your own thinking or about thinking in general.
3) Tell me something that has changed about your thinking since the beginning of our coding unit.
4) Tell me something you have learned about thinking since the beginning of our coding unit.
5) How would you describe "metacognition" in your own words?
6) What was your favourite part of the coding unit? (it doesn't have to be about thinking or metacognition).

### *Think-Aloud Assessments*

Think-aloud assessments (TAAs) also had both support and critique in the literature. TAAs have been found to be more reliable and predictive of actual academic achievement (Jacobse & Harkamp, 2012; O'Neill & Abedi, 1996; Schellings et al, 2013). However, they can be time consuming, and can interfere with the learning process (Akturk & Sahin, 2011; Veenman & Alexander, 2011). Specifically, being made to think aloud can slow down or interfere with thought processes, especially for those struggling with or new to a task. When all of one's cognitive focus is required for the task, the additional demands of verbalizing thoughts can be obtrusive (Veenman & Alexander, 2011). An additional point about TAAs, which I saw as potentially both a strength and a weakness, is that TAAs are necessarily task or domain dependent – they cannot be used to measure generalized metacognitive skills (O'Neill & Abedi, 1996).

While I wanted to get a picture of students' generalized metacognitive skills, this inquiry was focused on coding. Because of this, I decided to have students think aloud while engaged in a coding related problem-solving tasks. Students used iPad® mobile digital devices to play with the Lego Mindstorms Fix the Factory application program. After becoming familiar with the program and finding a level that challenged them, students used the iPad® mobile digital devices to record each other thinking out loud while solving or attempting to solve the level they chose. Their recordings were transferred onto a computer to be listened to.

### *Assignments Reflections*

Citing the above challenges with think-aloud assessments, and the inconsistent findings of validity for self-report questionnaires, Jacobse and Harkamp (2012) set out to develop an alternate metacognitive assessment tool. They developed a procedural test, where students had to report on their thinking and strategies while completing a short task. They compared results from their assessment tool with questionnaires, TAAs, and academic achievement, concluding a high degree of validity for their assessment. In addition to validity, they identified ease and speed of administration as a strength of their tool.

Throughout the coding unit, students completed a number of tasks inspired by this form of assessment. These tasks included planning activities, reflections, and short assignments designed to elicit and illustrate students' thinking and metacognitive activities. The tasks were developed on an ongoing basis throughout the coding unit, in consideration of students' response to each activity, such as whether or not it seemed helpful, accessible, or engaging to students. Appendix 3 contains a selection of the tasks students completed. I have chosen to share the ones that were more successful at supporting or illustrating students' thinking.

### 2.2.2 Ethical considerations

Several ethical considerations were relevant for this study. It was important to me to consider the best interests of my students in regards to digital citizenship and online safety, clear communication and consent from families, and accessibility for all students in the class.

#### *Student Interests*

I engaged in this inquiry project as both a researcher and an educator. The most important consideration for me in this inquiry arose from ensuring I engaged ethically in both of these roles. It was clear to me that my priority in either role was ensuring my inquiry was designed with my students' best interests in mind. As an educator, the role I prioritized, I designed all classroom activities in line with current curricula and with my best knowledge of how to teach and support students in my classroom. I created a unit I felt was engaging, meaningful, and empowering for students. As a researcher, I created a project intended to benefit the population I was studying (my students), and designed my data collection to fit within regular classroom activities, to ensure I was not disrupting student learning through my research. In both roles, my actions were driven by prioritizing student interests.

### *Digital Citizenship, Online Safety, Communication, Consent*

I chose to use Scratch, a web-based application, for teaching coding to my students. This decision was made based on the educational value and age appropriateness of the program. Scratch is accessible and engaging to most learners at a grade 5/6 level; it is easy to get started with, and offers the possibility of creating complex programs for those students who seek greater challenge. Additionally, students are able to interact within Scratch, by sharing their programs and commenting on others'. This is highly engaging for students.

Scratch does, however, come with some concerns. Because the program is online and involves interaction with others, it was important for students to be aware of online safety concerns and responsible digital citizenship. Because data for Scratch is stored in the U.S., it was important to consider how this would affect student privacy. To address online safety and student privacy, I created anonymous student accounts connected to my teacher account. Student accounts contained no identifying information. This meant that they would not have identifying information stored outside of Canada, and if they interacted on Scratch with individuals outside of the class, their identity would be unknown. Before beginning to use Scratch, we discussed as a class the importance of sharing responsibly online – not identifying themselves to others, or sharing any personal information. School board approved notices were sent to families informing parents/guardians about freedom of information and protection of personal information (FOIPPA) concerns. Students only used Scratch with parents'/guardians' approval. Students only shared their programs publicly if parents/guardians gave them permission to do so. As of writing this report, our class is continuing to use Scratch for other projects until the end of the school year. At the end of the school year, a notice was sent home informing parents that our Scratch classroom will be closed and all student accounts will be deleted. This provided students the opportunity to either discontinue using Scratch, knowing their accounts are closed, or to create individual accounts to continue using Scratch under appropriate parent/guardian supervision.

In addition to informing families about online program usage, it was important for communication to include letting parents/guardians and students know that I was working on my master's degree while completing this unit. Students were informed in a class discussion, and a notice was sent home to parents regarding the focus and content of my inquiry. Consent was requested to use student responses to demonstrate results of the study. No student responses were used directly without consent (although all student responses were used to identify themes that emerged in the study.

***Accessibility***

The class being studied included two English language learners, and one student with autism. It was important to me to ensure that all students could effectively engage in classroom activities and access all assessment and data collection tools. Both English language learners were coached through using Scratch until they indicated comfort with using it. I checked in regularly with them to ensure they continued to feel comfortable, understand how to use it, and understand the language they needed to use in Scratch. When they completed the pre-assessment questionnaire, they were assisted for understanding by the ELL teacher at the school. When they completed the post-assessment questionnaire, they were offered the choice to work with the ELL teacher to complete it.  Both students declined, indicating they were comfortable enough with their understanding to complete the questionnaire independently.

To ensure access and learning, the student with autism was sometimes supported by an educational assistant (EA).  The EA supported the student in task comprehension, learning, focus, and persistence.  Many of the activities were completed independently.

## Part 3: Evaluation

**Field Note 7: Evaluation**

About a week after completing my last data collection for this inquiry, and before I started the analysis of this data, I was introducing a new social studies activity to the class. We were going to do mystery Skype, an activity where you use Skype to connect with a class somewhere else in the world, asking each other yes/no questions to figure out where the other class is. As an introductory exercise, I did a twenty questions activity with my class, where they tried to figure out a character I was thinking of. The purpose was to get them thinking about what sorts of questions would be effective at narrowing down the possibilities, in order to try to guess as quickly as possible.

After the twenty questions, I asked the class, "why do you think we might have done this activity?" One of my students responded, "I think maybe this is about metacognition, because we are all now thinking about this problem, and we have to be aware of how our thinking is helping us solve the problem" (quoted to the best of my recollection, written down at the end of the school day it was said). I could not stop grinning. This reflected what was to me one of the most exciting results of the coding and metacognition unit. A student was spontaneously, with no prompting whatsoever, demonstrating and discussing their awareness of their thinking and their awareness of their metacognition. This didn't emerge as a major theme in results, and as such I haven't discussed it further in the paper, but it was one of the most rewarding moments of my master's inquiry. Was I effective at fostering the development of metacognitive skills in my students? I think this student offered a clear answer.

### 3.1 Findings, Analyses, Interpretation

The findings in all the data collected are interesting. I will look at quasi-quantitative data collected through the surveys and observational data collected through short answer responses on the surveys, classroom discussions, assignments, and think-aloud assessments (TAAs).

#### 3.1.1 Quasi-Quantitative Data: Multiple-Choice Questions

Quasi-quantitative data (qualitative data measured by frequency of response) from questionnaire responses was compiled to determine the number of each response for each multiple-choice question. The data were graphed to enable visual analysis of trends in student responses. Most of the questions were worded such that a positive answer would indicate use of metacognitive skills. An improvement in the class would be indicated by a shift towards a greater number of students responding with *usually*, *always*, or *sometimes*, and fewer students responding with *never* or *usually not*. I predicted that the multiple-choice questions would show a clear increase in the use of specific metacognitive thinking skills by students. The results were not as distinctive as anticipated. However, while not extreme, an improvement was displayed in the results of many of the questions. One example is question 7) Once I choose a strategy to solve a problem, I can explain why I chose it. In the pre-assessment responses, three students responded *never* and eight students responded *usually not*; in the post-assessment responses, no students responded *never*, and only five students responded *usually not*. This means that six fewer students out of a small sample size responded with either *never* or *usually not*. Several examples of questions demonstrating improvement of metacognitive skills (including question 7) are shown in table 4.

*Table 4* Results for Selected Pre- and Post-Assessment Questionnaire Items Demonstrating Improvement in Skills

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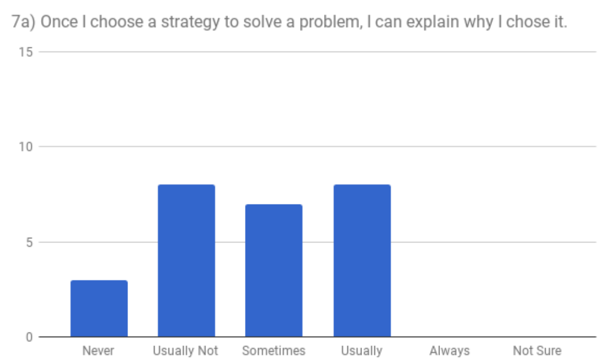

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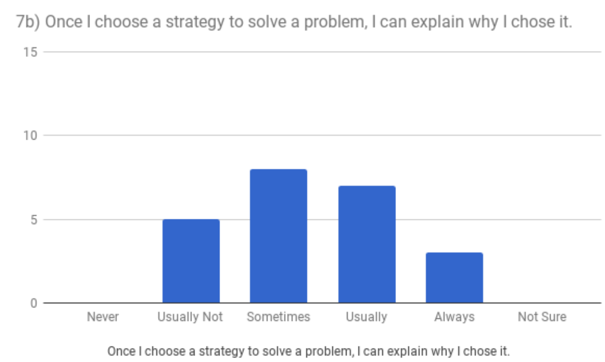

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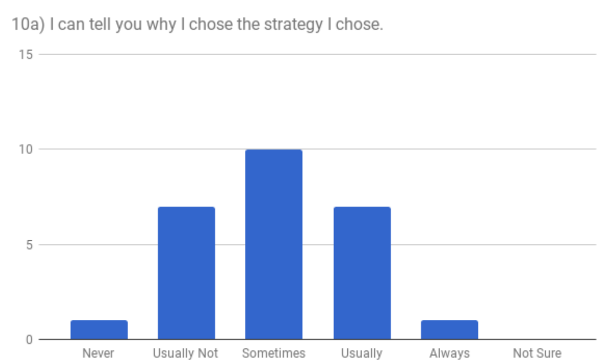

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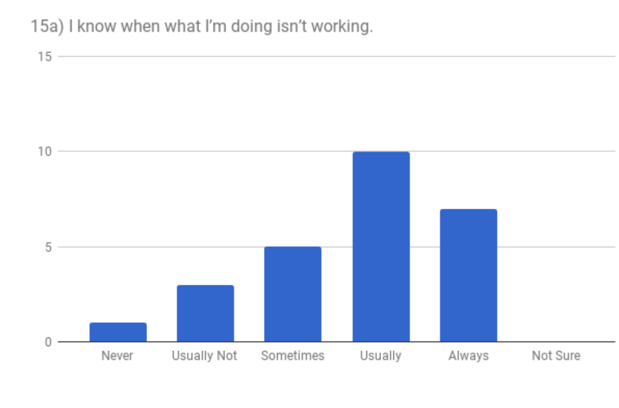
<td>
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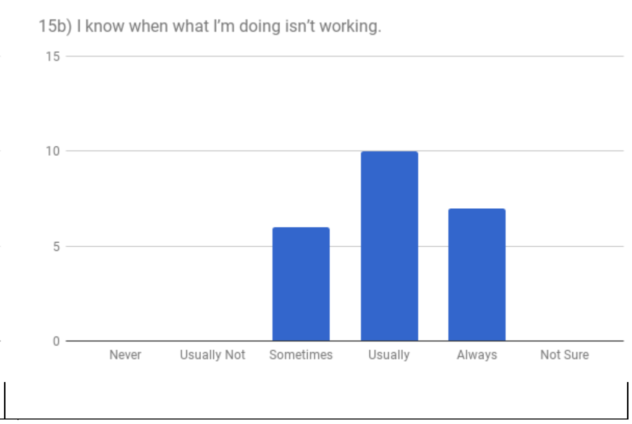
<td>
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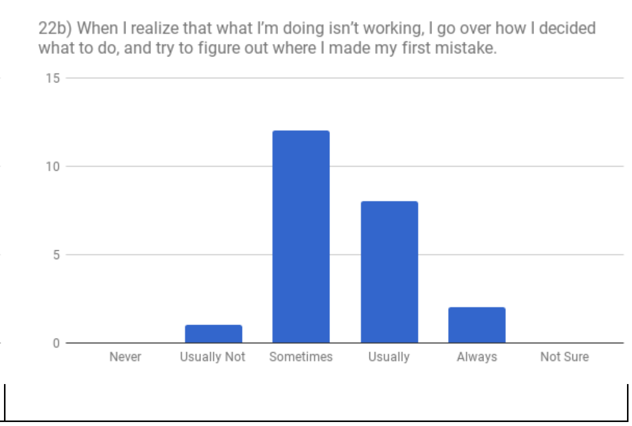
<td>
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</table>

Some post-assessment responses demonstrated a negative shift or no significant shift from the pre-assessment. Several examples are shown in table 5.

*Table 5* Results for Selected Pre- and Post-Assessment Questionnaire Items Demonstrating Negative or no Change in Skills

<table>
<tr>
<th>Pre-Assessment</th>
<th>Post-Assessment</th>
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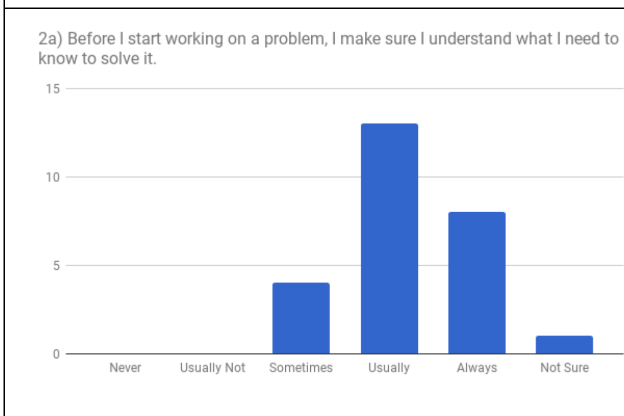
<td>
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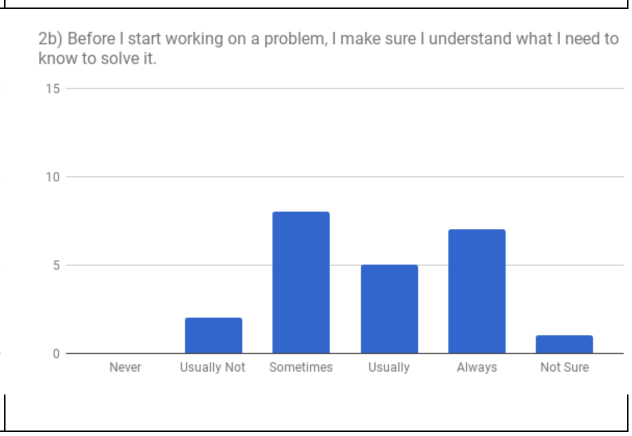
<td>
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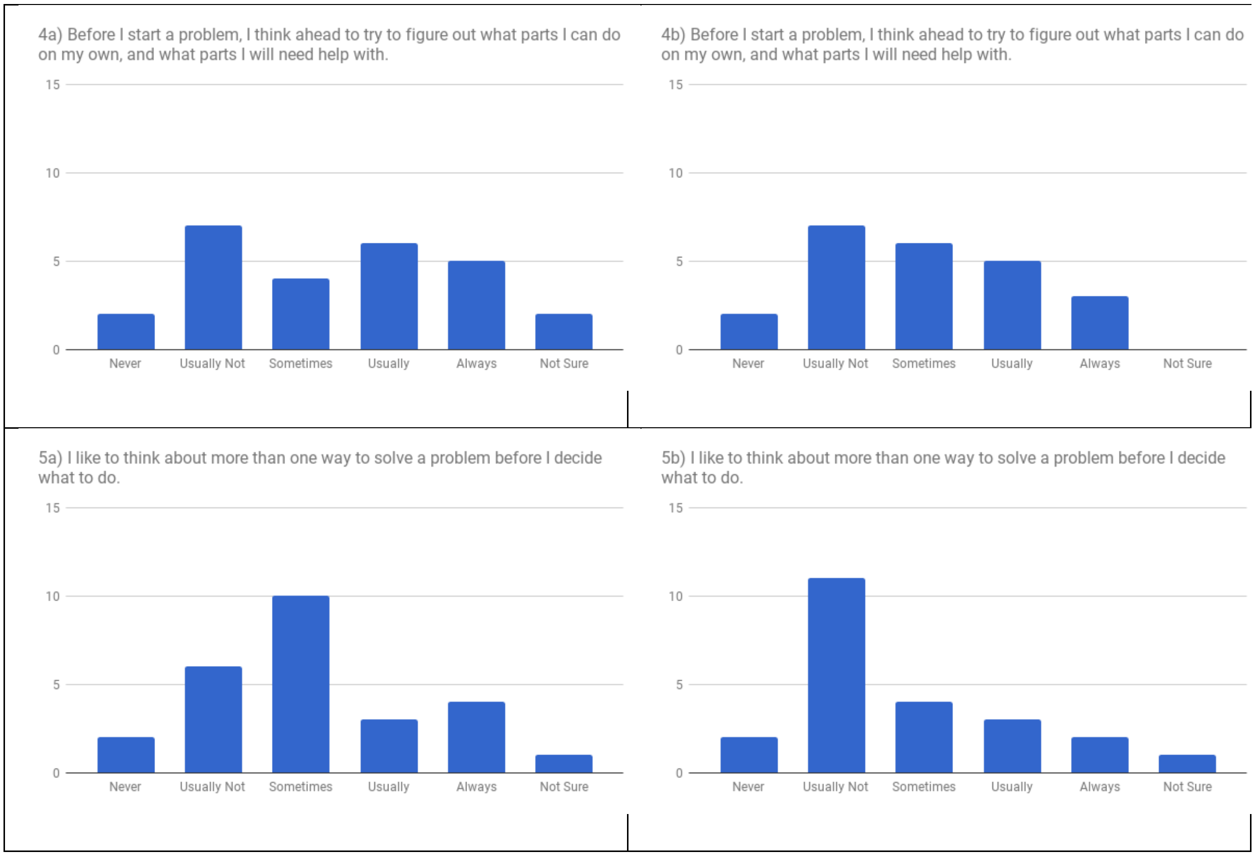



Appendix 4 contains results in bar graph form for all the multiple-choice questionnaire items.

While the data from the questionnaires are inconclusive, it does not suggest that students' metacognitive skills did not progress throughout the unit. Several things are important to consider. The total number of respondents was not the same for pre- and post-assessment questionnaires, due to student absences. The pre-assessment questionnaire had 26 respondents, while the post-assessment questionnaire had 24 respondents. Considering the small sample size, a difference of two respondents is significant, and could impact results significantly. Students indicated understanding of the questions, suggesting misunderstanding questions did not have a significant impact on results. One other consideration is that, similarly to Missiuna et al. (1987), the short length (two months) of the classroom study might limit progress of generalizable metacognitive skills. Perhaps such a questionnaire would be better at identifying change in student skills over a longer period. Another possible source of error could be that as students become more aware of metacognitive skills, they might more accurately report their use, leading to inconsistency in reporting before and after the unit. For example, students might think they are performing a skill, then learn they are not doing it (or not correctly), therefore reporting a decrease in use even though their skill awareness/ability has increased.

With all these considerations, I think that the moderate increase in metacognitive skill usage reported through the questionnaires is promising. While it does not show tremendous growth in student metacognitive skills, it does suggest that skills or awareness of skills may have been emerging. Short-answer responses, classroom observations, assignments, and TAAs contain further evidence to support this interpretation.

### 3.1.2 Qualitative Data

#### *Think Aloud Assessments*

Think aloud assessments (TAAs) were completed at the beginning and at the end of the unit. Students were instructed to say out loud what they were thinking while solving a level on a Lego Fix the Factory, a game designed to introduce coding skills to students, by having them program a robot to pick up blocks and move them to the right place, while navigating various obstacles. One important limitation to this data exists: after the pre-assessment TAAs, I noticed that most students were only reporting on what they were doing, not what they were thinking. In the post assessment TAAs, some students received some 'coaching' from the teacher to remind them to share their thoughts out loud. While this coaching was minor (coaching only involved a repetition of the exact same instructions that were given at the start of both pre- and post-assessment TAAS. Students were only reminded to think out loud, and do their best – no other instructions were given), it does affect the validity of the data. It is not possible to know how much students' thinking aloud changed because of what they learned in the unit, and how much it changed because of the reminders from the teacher to share their thoughts. Three students were selected to highlight some interesting shifts in thinking demonstrated between their pre- and post-assessment TAAs. The recordings of their TAAs were transcribed, partly word for word, and partly abridged to highlight the gist of what was said, and/or to highlight other actions that were relevant to demonstrating thinking (aside from spoken words). Themes in each students' TAA have been identified and discussed. For confidentiality, students have been called S1, S2, and S3, and gender neutral pronouns have been used. Full transcripts of the TAAs discussed here are found in Appendix 5.

**S1**

S1 was a student who demonstrated a lot of growth throughout this unit. For their pre-assessment TAA, they chose a level that was very easy for them, and their recording mostly consisted of describing the actions they were programming the robot to do. Just before running their script, they did indicate a decision to "see if this works", demonstrating a consciousness of testing out their ideas.

For their post assessment TAA, S1 chose a level that was challenging to them. They demonstrated a lot more intentionality in their programming. They started off by stating their goal for the level, and referring to one of the obstacles they would have to navigate. They indicated making an interim goal of navigating this obstacle, and a decision to test that out. When their first attempt didn't work out, they specifically stated what was needed to fix it, indicating intentionality in watching the program run, and checking for where the error was. When that obstacle was solved, they identified another interim obstacle, and their awareness of how it worked. They made a prediction for what would solve it, using a partly unfamiliar feature of the level (but connecting it to a previous level where the same feature existed, but did something slightly different). They indicated a decision to test out their theory, tested it, and found that it worked.

Through their TAAs, S1's increase in verbalizing their thinking suggests a significant increase in their awareness of their thinking. They also demonstrated an intentionality in their thinking and actions (i.e. relating their actions to a goal) that was not displayed in the pre-TAA. This suggests an improved ability to identify a problem, regulate their thinking, and make conscious choices based on the problem to be solved. In their pre-assessment, the only specific thinking process S1 explicitly expressed was testing out an idea (execution and monitoring). In the post-assessment, they explicitly expressed a larger number of thinking processes, including: identifying a goal, making a plan, testing out a theory, connecting to previous knowledge, and elaborating on previous knowledge. This suggests an increase in awareness and regulation (i.e. intentional use) of thinking processes.

**S2**

S2 demonstrated a variety of thinking skills in both the pre- and post assessment TAAs. This suggests they started the unit already having some strong and conscious thinking skills. For example, in their pre-assessment TAA, they demonstrated understanding their goal and some thinking ahead through their solution by making corrections without running the program. However, their surprise at the outcome of their program also suggests that maybe they weren't too focused on the solution. They demonstrate an awareness of when their thinking isn't working, and an awareness of their own frustration in their responses to when the code they wrote doesn't work.

However, what really struck me in S2's post-assessment questionnaire was how much they slowed down and demonstrated intentionality in creating their code. Before entering any code, they verbalized the commands they thought they would use, while also making hand movements to demonstrate and orient themself. This was done slowly, and carefully, making it evident they were mentally checking each step. They then entered the code, and indicated a decision to test out their work. When it didn't work, they looked over the code, identified specifically which step made the program not work, and identified a solution. While their pre-assessment TAA seemed more random, and resulted in taking several attempts to complete the level, their slowed down, intentional approach to their post-assessment TAA required only two attempts to solve.

Through their TAAs, S2 demonstrated an increase in intentionality in their thinking, and an increase in thinking skills and processes they were able to apply. They demonstrated understanding a goal, planning ahead, mentally checking before applying a solution, and debugging by checking for which part of a strategy did not work.

**S3**

S3's pre-assessment TAA was very short. They said out loud the steps that they took, and then indicated "That is what (they were) thinking". I found that statement interesting, as it demonstrated they were aware that they were sharing their thinking, while the rest of their recording did not demonstrate what that thinking was. It is likely that this level may have been too easy for this student, which may have contributed to the students limited awareness and expression of their thinking (i.e., perhaps they were easily able to solve the level using unconscious cognition).

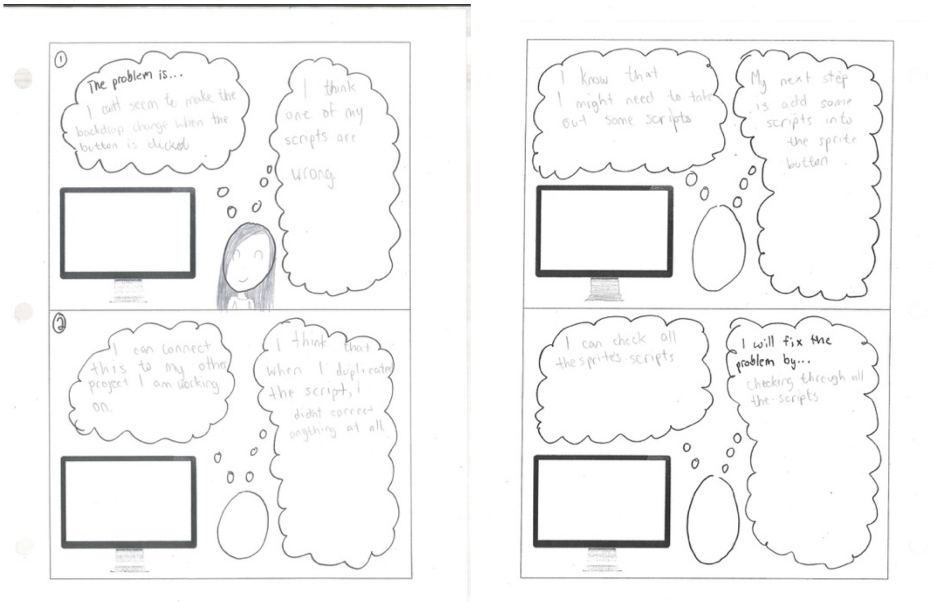
S3's post assessment was very long. They chose a level that was difficult for them, and communicated a complex range of thinking processes and skills. They began by identifying the process they chose for solving the level ("I want to do this step by step"). This indicated an intentionally chosen strategy of breaking up the problem into smaller pieces (and also an awareness of the level of personal challenge). They then identified their knowledge about the obstacles on the level, and indicated thinking about making a decision. This indicated an intentional strategy to understand the problem and an awareness of making a decision. Several times throughout the post-assessment TAA, S3 indicated that thinking out loud made thinking more difficult (this supports the idea that TAAs can be problematic for interfering with the thinking process (Akturk & Sahin, 2011; Veenman & Alexander, 2011). S3 continued to identify what they knew about the next step of the level, and what they thought they needed to do next. This was repeated for several steps of the complex level, demonstrating an ongoing awareness of what has already been solved, what is next, and how steps fit together. After trying several ideas, S2 started expressing frustration, but also expressed a belief there was something they must have missed. This demonstrated a willingness to try multiple strategies, and a conscious decision to approach the problem with a growth mindset (their expressions of frustration were framed in such a way that they never indicated giving up, or thinking of themselves as unable to solve the problem). After persisting despite this frustration, S3 indicating realizing a piece of information they hadn't previously realized (demonstrating awareness of adding new information into their decision making), and decided to try one more thing. After several more attempts guided by this new information, they succeeded. S2 then demonstrated evaluation skills by saying, "I made a (big) mistake. I could have saved a lot of moves". There was, in fact, a much shorter solution to the problem. By recognizing this, S3 demonstrated assessing their own solution after completing it.

S3 is a student who started the metacognition unit with many strong thinking skills. What really stands out in the contrast between their two TAAs is how their ability to express these thinking skills emerged through the unit. This suggested both an increase in ability and an increase in awareness when it came to applying thinking skills and processes.

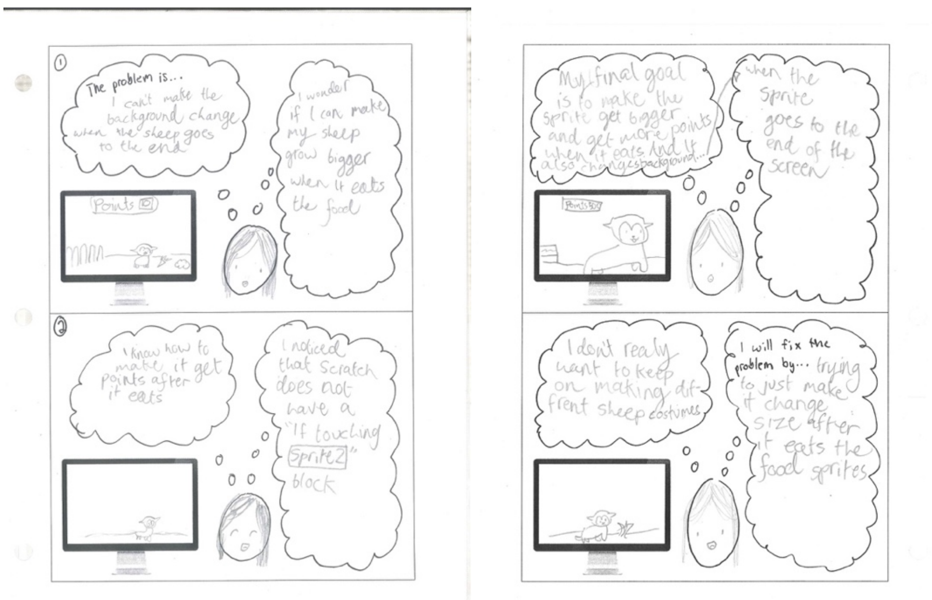
#### ***In-Class Assignments***

Most of the in-class assignments were aimed at teaching and guiding students in their development of metacognitive skills. They involved a lot of prompting for responses, and as such the data collected in not necessarily indicative of students' independent abilities. However, one more open-ended assignment provided rich insight into students' thinking. Students filled in thought bubbles on a comic strip to indicate their thought process while solving a problem with one of their Scratch programs. Student responses were so interesting and rich, I decided to repeat the activity with planning for a new program. Both comics involved some prompting. For the first comic, the students were given a page of sentence starters they could choose from if they wanted; for the second one, sentence starters were put onto the page (in response to a number of students expressing difficulty looking back and forth between two pages). Many students indicated the sentence starters on the page were helpful. However, I didn't entirely like them because I felt like it constrained student responses. Both sets of comics were fascinating and enjoyable to read. Some examples are attached below (with analysis following).

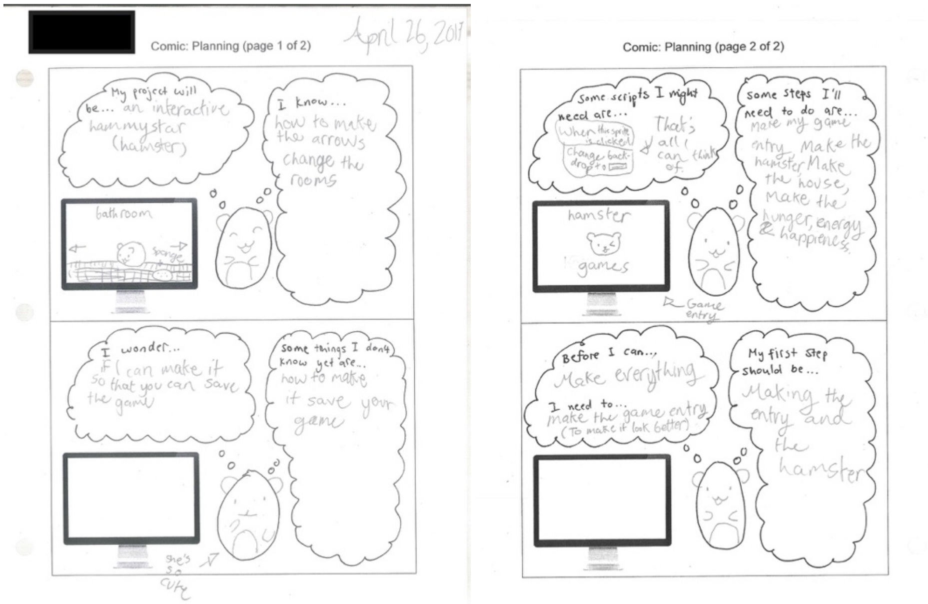
*Table 6* Selected "Thinking" Comics by Students



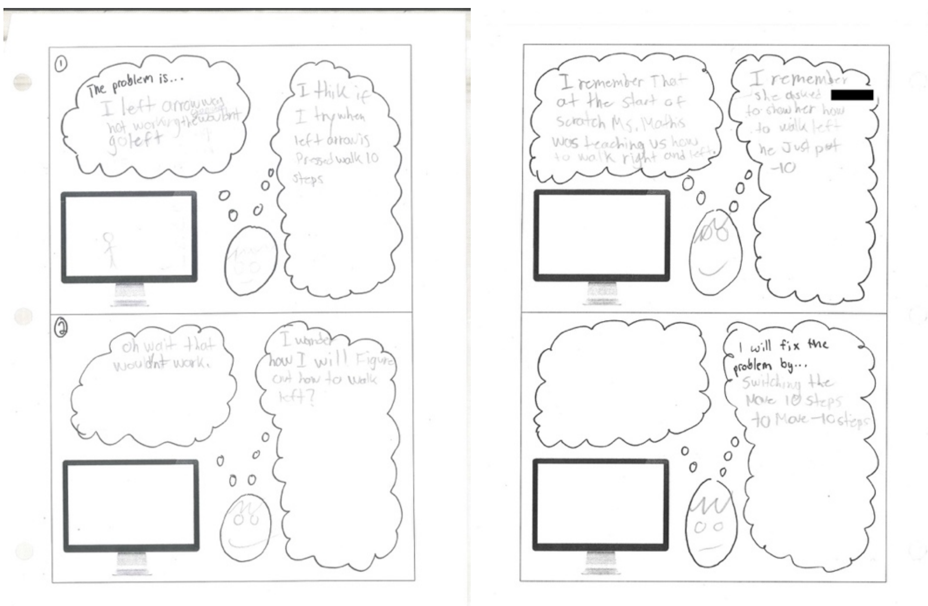

By S4



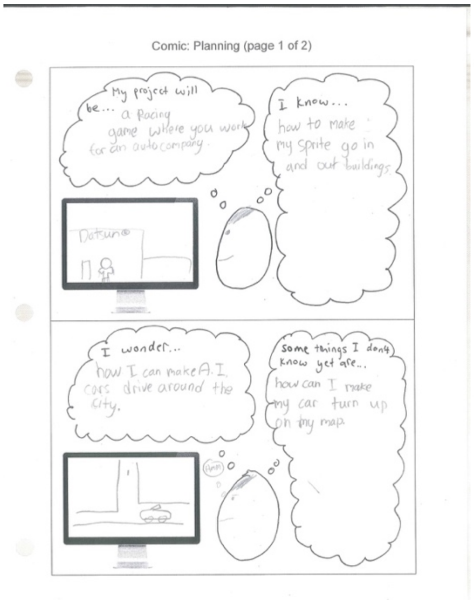

By S5

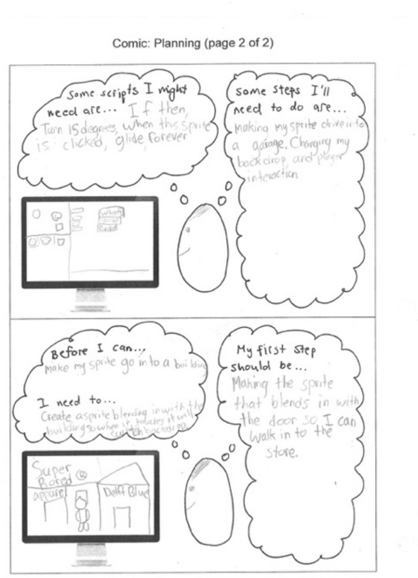

[redacted]
Comic: Planning (page 1 of 2)
April 26, 2017
My project will be... an interactive hammystar (hamster)
I know... how to make the arrows change the rooms
bathroom
I wonder... if I can make it so that you can save the game
Some things I don't know yet are... how to make it save your game
she's so cute
Comic: Planning (page 2 of 2)
Some scripts I might need are... When this sprite is clicked, Change backdrop to
That's all I can think of
Some steps I'll need to do are... Make my game entry, Make the hamster, Make the house, Make the hunger, energy & happiness
hamster games
Game entry
Before I can... Make everything
I need to... make the game entry (To make it look better)
My first step should be... Making the entry and the hamster

By S5


1
The problem is...
I thik if I try when left arrow is Pressed walk 10 steps
2
oh wait that wouldn't work.
I wonder how I will figure out how to walk left?
I remember That at the start of Scratch Ms. Mathis was teaching us how to walk right and left.
I remember [redacted]
to walk left he just put -10
I will fix the problem by... Switching the Move 10 steps to Move -10 steps

By S6




By S7

The students really engaged in drawing these comics. They indicated through verbal commentary that they preferred this to thinking out loud, which they found disruptive. The students demonstrated rich awareness of their thinking, and a variety of metacognitive skills through the comics.

S4 demonstrated a thoughtful self-checking process. They theorized what was causing problems, reflected on their own actions that caused the problem, and used this to guide the solution. They also demonstrated making conscious connections to previous learning, which indicates both planning and elaboration skills (using previous learning to guide current action).

I have included two comics by S5, in part to illustrate how student thinking often demonstrated equal levels of complexity with and without prompting, and in part because they really demonstrated how students could often enrich their descriptions of their thinking through images. In the first comic, S5 demonstrated a thoughtful process of breaking down their program into steps, solving individual problems, and connecting them together. They demonstrated intentionally paying attention to the resources available to them (the scripts available on Scratch). They also demonstrated awareness of multiple solutions and understanding of their reason for choosing a solution (looking for efficiency in not making repeats of the same costume). In their second comic, S5 once again demonstrated a strong ability to break down a goal into steps, and identify a suitable course of action. They showed awareness of their abilities and where they needed help. Their images in both comics indicated a strong ability to visualize and plan ahead.

S6's comic focused in on one very specific problem. By doing this, they demonstrated a precise awareness of the details of their thinking broken down into small steps. They also indicated an intentional decision to review past learning in order to find a solution to their problem, suggesting strong planning and connecting skills.

Like S5, S7 also used images demonstrating a strong ability to visualize and plan ahead. They described different steps and layers of their program, and how those layers fit together. This suggested a strong ability to break down a problem into steps, and sequence a solution. Like S6, the detail in S7's explanation suggested awareness of the details within a larger thought process.

### ***Questionnaire Short Answer Questions***

Students gave interesting and thoughtful answers to the short answer questions on the questionnaire. I have chosen to focus on their post-questionnaire responses, as these give a picture of where students were at after the coding and metacognition unit. In questions one, two, and four, students demonstrated general engagement, awareness, and thoughtfulness regarding metacognition. Even when expressing difficulty, students were demonstrating awareness and thoughtfulness regarding their thinking, because they were aware of that difficulty, and looking for solutions.

*Table 7* Select Responses Illustrating General Engagement, Awareness, and Thoughtfulness Regarding Metacognition

| Question | Responses |
| --- | --- |
| Tell me something you have noticed about your own thinking. | - I noticed that the pictures I see in my head/mind are very detailed and vivid.<br>- I don't always know what I am thinking.<br>- I noticed that I don't like giving up<br>- I have noticed my thinking has been working a lot lately<br>- I noticed that when I think about something but then I get distracted then I forgot my thinking. |
| Tell me something you wonder about your own thinking or about thinking in general. | - I wonder how thinking works<br>- I wonder how thinking works in your brain like how does it just come up.<br>- How (our) brains help us do (our) work<br>- I sometimes wonder why I can't figure out something easy |
| Tell me something you have learned about thinking since the beginning of our coding unit. | - Thinking is very important (I mean knowing what you're thinking)<br>- That metacognition really helps out a lot |

In questions one, three, and four, students reported growing confidence with their thinking awareness and abilities, as well as increased use of specific metacognitive strategies.

*Table 8* Select Responses Illustrating Growing Confidence and Use of Metacognitive Strategies

| Question | Responses |
| --- | --- |
| Tell me something you have noticed about your own thinking. | - I like to figure out what's wrong with my mistakes.<br>- (I) can predict the outcomes of things more easily by remembering situations like it and the final result.<br>- I've noticed that I've been trying to focus when ever I'm thinking. |
| Tell me something that has changed about your thinking since the beginning of our coding unit. | - I can solve and process problems a little bit faster.<br>- Not really much, but I find it easier to solve problems.<br>- I pay more attention to what I'm thinking<br>- I start looking where the problem started after the coding unit.<br>- When I just started scratch I didn't think of any complex games because there were some |

| | |
|---|---|
| | things I didn't understand but after awhile I understood and I have a lot of ideas of what game I should make. |
| Tell me something you have learned about thinking since the beginning of our coding unit. | - I learned that thinking has a system and that you have to think using that system so you can think properly.<br>- That metacognition really helps out a lot<br>- I have learned that my thinking is getting better<br>- When we are orienting and planning it means we look at what our ideas are and we plan how it's going to be. |

Student responses clearly demonstrate a strong awareness of metacognitive strategies, and confidence applying these strategies. Continuing with the idea of awareness, students were asked what their understanding of the word metacognition was.

*Table 9* How Would You Describe Metacognition in Your Own Words? – Select Student Responses

| |
|---|
| - I would describe meta cognition as the system in our brains that helps us think properly.<br>- Orientation and planning is before execution and monitoring<br>- It's like thinking about your thinking<br>- Being able to think fluently and understanding what you need to do.<br>- I think that metacognition is all about how you think<br>- Metacogniton is when your brain is turning and your thinking about the (things) you heard or saw or just plain thinking.<br>- Meta cognition … has something to do with paying attention to your thinking |

When the unit was first introduced, only one student had ever heard the word before, and none of the students indicated any understanding of the word. Their responses to this question at the end of the unit demonstrate clear understanding and an excellent ability to express their thinking...about thinking…about thinking.

### 3.1.3 Summary of Results

The results of this study were very promising and exciting in terms of answering my inquiry question. Results suggest that the coding/metacognition unit was effective at fostering the development of student metacognitive skills. Multiple-choice questionnaire items suggested some growth in metacognitive skills. Qualitative observations through think aloud assessments, classroom assignments, and short-answer questionnaire items demonstrated growing awareness and application of metacognitive skills, as well as increased confidence regarding these skills.

# Part 4: Elaboration

## 4.1 Limitations, Recommendations

Several limitations have affected the implementation and results of this study. One limitation is sample size and consistent sampling. There were 27 students registered in the class throughout the study. This was already a small study size. Additionally, several students had short, repetitive, or extended absences during this time. This affected consistency of instruction for all students, response rates for assignments, participation in think-aloud assessments, and response rates for questionnaires. The small size of the sample limits the generalizability of the results. Future study would likely benefit from a larger sampling size, such as multiple classes (like Missiuna et al., 1987). However, with this approach, other challenges might present, such as teacher consistency (Littlefield et al., 1989; Linn, 1985). This could perhaps be addressed by having a visiting teacher run the same program with multiple classes, or through coordinated training of classroom teachers.

An additional limitation with the multiple-choice data is the uncertain validity of self-report questionnaires as discussed in the literature review (Gascoine et al., 2016; Jacobse & Harkamp, 2012; O'Neil & Abedi, 1996; Schellings et al., 2013). While the multiple-choice data suggested some improvement, it is possible that this data was not accurately reported by students. The possible lack of validity of self-report questionnaires was addressed through the use of multiple data collection methods.

Time is also another limiting factor. The length of the in-class unit for this study was two months. The short length of time may have limited the potential for student learning (Littlefield et al., 1989; Missiuna et al., 1987). As discussed above, this may have been particularly relevant for the multiple-choice questionnaire items, as they looked to identify general metacognitive skills. It is likely that generalizable metacognitive development would require more time. As such, the multiple-choice data cannot support or deny the effectiveness of coding as a means to learning general metacognitive skills. However, the qualitative data collected provide strong evidence from which to conclude that the unit was effective in supporting students' development of metacognitive skills. Further research could benefit from a longer term study of coding and metacognition. It would be interesting to see how both qualitative and quasi-quantitative data might change or extend over a longer term classroom study.

Another limitation of the study is the inability to isolate the variables of learning activities and teaching methods. Explicit and effective teaching methods have been found to significantly impact student learning of problem solving and thinking skills (Linn, 1985; Littlefield et al., 1989). Learning may be very limited without explicit teaching (Littlefield et al., 1989). However, Papert (1980) observed significant thinking skill development in students, without reporting explicit teaching (his writing is suggestive of a primarily explorative approach to learning coding). Since my inquiry involved explicit teaching of both metacognitive and coding skills, it is impossible to conclude to what degree the results would suggest metacognitive development if students had used only an explorative approach to learning coding, or if metacognitive skills were not explicitly taught. Future study could benefit from isolating these components of the unit, to explore how much each impacted the final outcome.

**4.2 Conclusions**

Despite the short implementation time, the multiple-choice questionnaire results suggested some improvement in skill awareness and use. The qualitative data also provided strong evidence of metacognitive skill development. Considering results and limitations, I feel the data supports a conclusion that this unit was successful in fostering metacognitive skill development in my students.

**4.3 Next Steps**

Following this inquiry, several new questions emerge, which I would find interesting to explore. I wonder how a longer term in-class study of coding and metacognition, would impact students' metacognitive skill development, particularly regarding generalized use of metacognitive skills across subject areas. Also in the realm of generalization of skills, a meaningful next step might be to investigate how students' metacognitive skills have, or could be, generalized to other subject areas. While this study focused specifically on coding and metacognition, a bigger goal of mine is to support students in developing metacognitive skills in all areas. Additionally, I would like to explore further how think-aloud assessments (TAAs) can impact and illustrate student learning. As there is strong evidence supporting a connection between TAAs and metacognitive or problem-solving skills (e.g. Jacobse & Harkamp, 2012; Neuenhaus et al., 2011; O'Neil & Abedi, 1996), it might be meaningful to explore if TAAs only demonstrate metacognitive skills, or if student metacognitive skills could be enriched by practicing and improving their ability to think out loud.

## Epilogue: Elaboration – Coding for Social Change

Almost 12 years ago, while finishing up my undergrad degree in social work, I told myself that if I ever did my master's degree, I would want to study how gendered language impacts children's (and especially girls') development. While the connection might not be obvious, I feel like I did not stray too far from this.

Vygotsky (1978) explains signs as something that is oriented inward, used to makes sense of and control the internal world. He identifies language as a sign used to make sense of the world and organize one's thinking. He identifies tools as oriented outwards, used to interact with and control the external world. But I think Vygotsky's (1978) signs could be understood as internal tools. And as such, language, as one of these tools, would expand our ability to understand and act on our internal world. Metacognition could then be understood as the set of signs to represent thinking - essentially a language of thinking. Building a vocabulary in this language of metacognition could enable one to act on their own thinking.

Gendered language can then impact how boys and girls differently develop these internal tools. White and Frederiksen (1998) discuss that gendered differences in science scores emerge as young as grade 6, and become bigger in older grades. They suggest metacognitive awareness and confidence plays a role in this, and if addressed at younger grades, while differences are smaller, then perhaps, as they get older, female students are more likely to retain the same confidence and abilities as male students.

Turkle and Papert (1991) explore gendered differences in learning to code. They identify two main approaches to learning coding: a hard approach, characterized as directed, systematic, rigid, objective, distanced, hierarchical, theoretical, and abstract; and a soft approach, characterized as flexible, connected, distributed, practical, and concrete. They acknowledge that society has placed unequal valued on these terms and characterizations, and decide to use them anyway, in intentional rejection of this unequal evaluation. Recognizing that all learners exist on a spectrum, they note that female learners are more likely to take a soft approach, and male learners are more likely to take a hard approach. This is likely impacted by socialization. However, academic settings (and especially scientific settings) tend to privilege the hard approach (Turtle & Papert, 1991); so, girls are socialized to take a soft approach to learning, but then this learning style, and the knowledge that comes out of it are devalued. I can't help but wonder what role this plays in the withdrawal of girls from sciences.

But to bring back some optimism, Turtle and Papert (1991) go on to explore how learning to code can break down this division and devaluation. The constructivist/constructionist environment of creating computer programs empowers both soft and hard approaches to learning both coding and thinking skills. In this way, coding becomes a tool for social change—empowering female students to engage more in a subject area they have felt excluded from, and empowering all students to access and value ways of thinking and learning that have historically been dismissed (Turkle & Papert, 1991). Always the feminist, I am always passionate about anything that holds the potential to empower my female students in a world that does not give them equal access as males. So, my excitement for coding and metacognition grows, as I discover my students are not only learning to code, and not only coding to learn, but maybe even coding to change the world.

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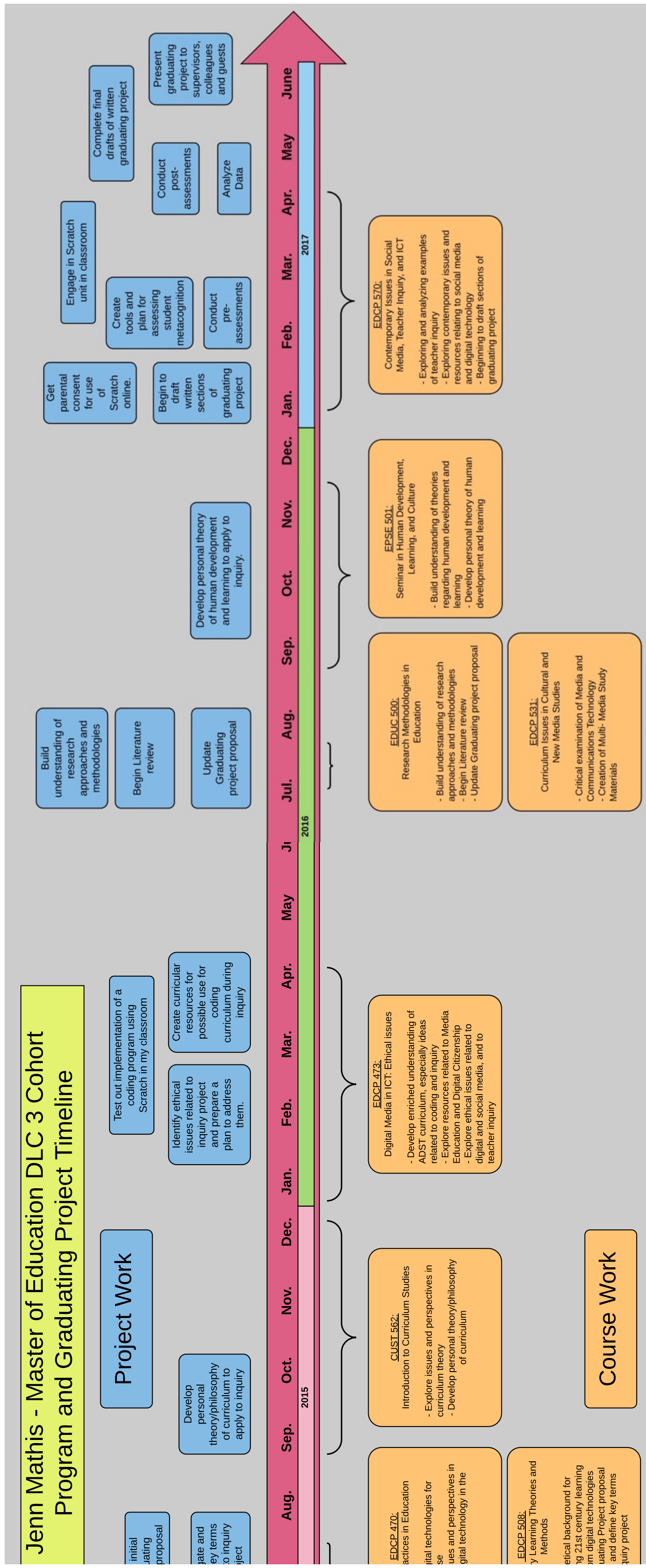
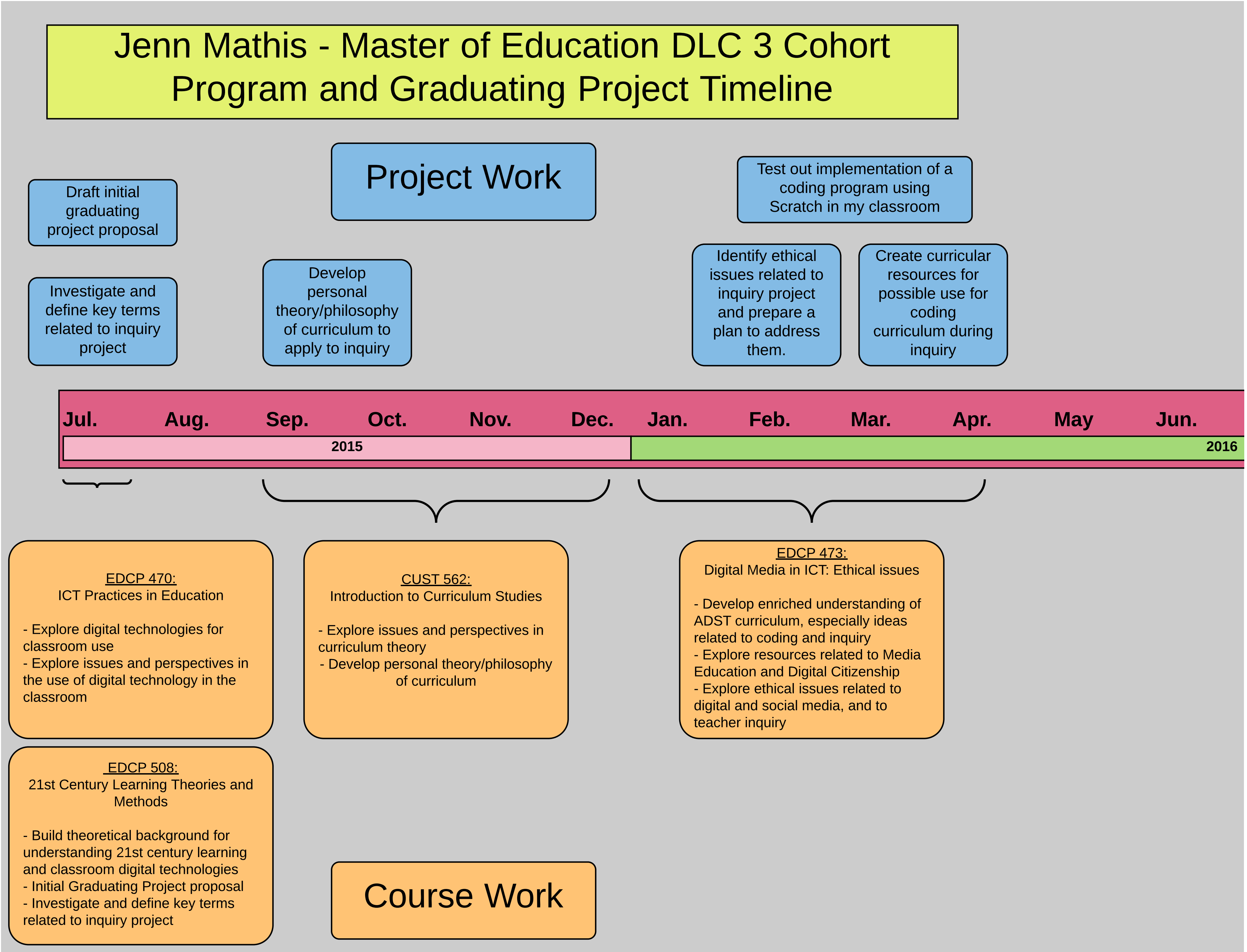
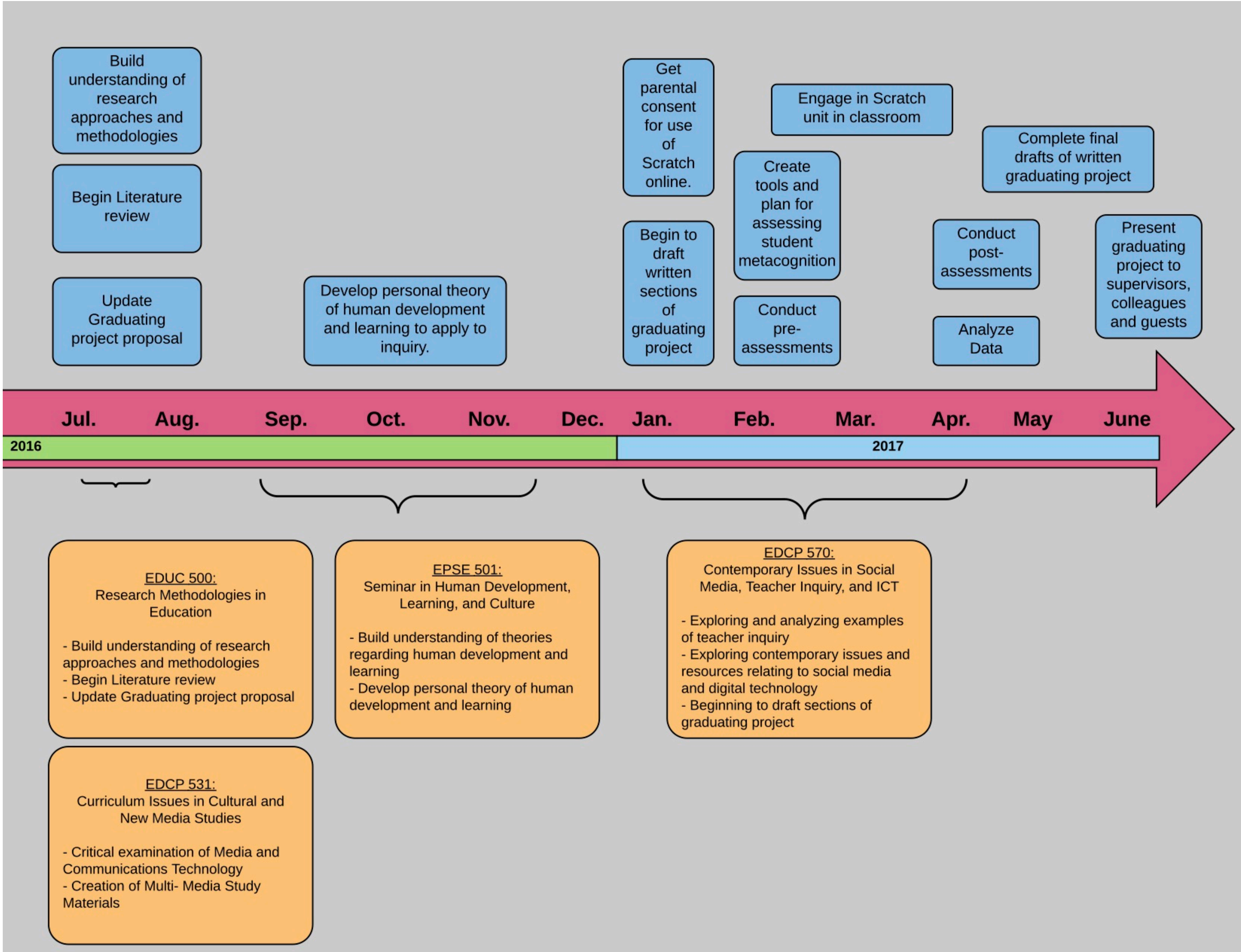
# Appendix 1 – Master's Program and Project Timeline

The timeline has been enlarged onto the following two pages for clarity.




Jenn Mathis - Master of Education DLC 3 Cohort
Program and Graduating Project Timeline
Project Work
Draft initial graduating project proposal
Investigate and define key terms related to inquiry project
Develop personal theory/philosophy of curriculum to apply to inquiry
Test out implementation of a coding program using Scratch in my classroom
Identify ethical issues related to inquiry project and prepare a plan to address them.
Create curricular resources for possible use for coding curriculum during inquiry
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
Jun.
2015
2016
EDCP 470:
ICT Practices in Education
- Explore digital technologies for classroom use
- Explore issues and perspectives in the use of digital technology in the classroom
CUST 562:
Introduction to Curriculum Studies
- Explore issues and perspectives in curriculum theory
- Develop personal theory/philosophy of curriculum
EDCP 473:
Digital Media in ICT: Ethical issues
- Develop enriched understanding of ADST curriculum, especially ideas related to coding and inquiry
- Explore resources related to Media Education and Digital Citizenship
- Explore ethical issues related to digital and social media, and to teacher inquiry
EDCP 508:
21st Century Learning Theories and Methods
- Build theoretical background for understanding 21st century learning and classroom digital technologies
- Initial Graduating Project proposal
- Investigate and define key terms related to inquiry project
Course Work


Build understanding of research approaches and methodologies
Begin Literature review
Update Graduating project proposal
Develop personal theory of human development and learning to apply to inquiry.
Get parental consent for use of Scratch online.
Begin to draft written sections of graduating project
Create tools and plan for assessing student metacognition
Conduct pre-assessments
Engage in Scratch unit in classroom
Conduct post-assessments
Analyze Data
Complete final drafts of written graduating project
Present graduating project to supervisors, colleagues and guests
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
2016
2017
EDUC 500:
Research Methodologies in Education
- Build understanding of research approaches and methodologies
- Begin Literature review
- Update Graduating project proposal
EDCP 531:
Curriculum Issues in Cultural and New Media Studies
- Critical examination of Media and Communications Technology
- Creation of Multi- Media Study Materials
EPSE 501:
Seminar in Human Development, Learning, and Culture
- Build understanding of theories regarding human development and learning
- Develop personal theory of human development and learning
EDCP 570:
Contemporary Issues in Social Media, Teacher Inquiry, and ICT
- Exploring and analyzing examples of teacher inquiry
- Exploring contemporary issues and resources relating to social media and digital technology
- Beginning to draft sections of graduating project

# Appendix 2 - Metacognitive Skills Inventory

This appendix shows the questions asked in my Metacognitive Skills Inventory, and how each of the multiple-choice items was developed. Each multiple-choice item was based on an I statement from one of the BC Curriculum Core Competencies. The I statements were adapted to focus on metacognitive skills and to make them easier for grade 5 and 6 students to understand. The inventory had questions focused on orientation and planning (referring to metacognitive activities that occur prior to beginning a task), execution and monitoring (referring to metacognitive activities that occur during completion of a task), and evaluation and elaboration (referring to metacognitive activities that occur after completing a task). Students responded to each item by selecting always, usually, sometimes, usually not, never, or not sure.

The short answer questions were designed to get a sense of students' awareness and use of thinking skills in general and specifically their own thinking skills. The post-assessment questionnaire included one modified question to be more applicable to the end of the unit, and three additional short answer questions to further assess student learning and engagement through the coding/metacognition unit.

Orientation and Planning

| Core Competency | I statement | Questionnaire Item |
|---|---|---|
| Creative Thinking<br><br>Communication | - I use my experiences with various steps and attempts to direct my future work.<br><br>- I am able to represent my learning and my goals, and connect these to my previous experiences | Before I start working on a problem, I think about similar problems I have solved before to help me decide what to do. |
| Communication | - I acquire the information I need for school tasks… | Before I start working on a problem, I make sure I understand what I need to know to solve it. |
| Personal Awareness and Responsibility | - I can recognize my strengths… | I know if a problem is going to be hard or easy for me. |

| | | |
|---|---|---|
| Social Responsibility | - I can solve some problems myself and can identify when to ask for help. | Before I start a problem, I think ahead to try to figure out what parts I can do on my own, and what parts I will need help with. |
| Social Responsibility | - I can clarify issues, generate multiple strategies…<br>- I can identify problems and compare potential problem-solving strategies. | I like to think about more than one way to solve a problem before I decide what to do. |
| Critical Thinking | - I can consider more than one way to proceed and make choices based on my reasoning and what I am trying to do. | Once I choose a strategy to solve a problem, I know why I chose it. |
| Critical Thinking<br><br>Communication | - I can consider more than one way to proceed and make choices based on my reasoning and what I am trying to do.<br><br>- I recount and comment on events and experiences.<br>- I communicate clearly, in an organized way. | Once I choose a strategy to solve a problem, I can explain why I chose it. |
| Critical Thinking<br><br>Personal Awareness and Responsibility<br><br>Communication | - I can consider alternative approaches and make strategic choices.<br><br>- I can set priorities; implement, monitor, and adjust a plan<br><br>- I am intentional and strategic… | Before I start a problem, I think about what order I will need to solve it in. (What to do first, second, etc.). |
| Critical Thinking | - I can explore materials and actions. | When I am working on a problem, I just start and see what comes out of my work. |
| Communication<br><br>Creative Thinking | - I am flexible and have a variety of strategies and experiences to draw on.<br><br>- I am willing to take significant risks in my thinking. | I am willing to try out a thinking strategy, even if I am not sure whether or not it will work. |

## Implementation and Monitoring

| Core Competency | I statement | Questionnaire Item |
|---|---|---|
| Communication | - I can answer simple, direct questions about my activities and experiences. | When somebody asks me a yes/no question about what I am thinking while working on a problem or |

| | | |
|---|---|---|
| Critical Thinking | - I can tell or show something about my thinking. | reading a book, I can usually answer them. |
| Communication | - I recount and comment on events and experiences. | When somebody asks me to describe my thinking when I am solving a problem, I can usually explain it clearly. |
| Communication<br><br><br><br>Critical Thinking | - I…integrate new information….<br>- I acquire, critically analyse, and integrate well-chosen information.<br><br>- I can gather and combine new evidence with what I already know to develop reasoned conclusions, judgements, or plans. | When I get or figure out new information, I check how it fits with what I thought before. |
| Creative Thinking | - I make my ideas work or I change what I am doing. | I know when what I'm doing isn't working. |
| Creative Thinking | - I can usually make my ideas work within the constraints of a given form, problem, or materials if I keep playing with them. | When something I'm doing isn't working, I try to figure out why. |
| Critical Thinking | - I can explore | When something I'm doing isn't working, I erase it and try the same thing again. |
| Social Responsibility | - I can solve some problems myself and can identify when to ask for help. | When I'm working on a problem, I know when I need help. |
| Personal Awareness and Responsibility | - I can sometimes recognize emotions<br>- I can tell when I am becoming angry, upset, or frustrated. | I know when I'm getting frustrated with a problem. |
| Personal Awareness and Responsibility | - I can use strategies that increase my feeling of well-being and help me manage my feelings and emotions.<br>- I have strategies to calm myself. | When I'm getting frustrated with a problem, I think about ways to make myself feel better. |
| Personal Awareness and Responsibility | - I can be focused and determined … and persevere with challenging tasks. | When I'm getting frustrated with a problem, I "freeze" or give up. |
| Critical Thinking | - I can examine and adjust my thinking.<br>- I can examine my thinking, seek feedback, reassess my work, and adjust. | When I realize that what I'm doing isn't working, I go over how I decided what to do, and try to figure out where I made my first mistake. |

| | | |
|---|---|---|
| Critical Thinking | - I can use evidence to make simple judgments. | I can tell when there is a mistake in my thinking, even though I don't always know why. |

Evaluation and Elaboration

| Core Competency | I statement | Questionnaire Item |
|---|---|---|
| Communication | - I offer detailed descriptions of my own efforts and experiences. | After solving a problem, I can explain how I did it. |
| Creative Thinking | - I use my experiences with various steps and attempts to direct my future work. | After solving a problem, I can think of other situations where a similar solution might be helpful. |
| Critical Thinking | - I can describe how my thinking is changing. | After doing a lesson or an assignment, I can tell you what changed about my knowledge and thinking from before the lesson or assignment. |
| Critical Thinking | - I am open-minded and patient, taking the time to explore, discover, and understand. | When I get stuck, or when I don't succeed at a problem or at part of a problem, I think about what I need to learn to succeed next time. |

Short Answer Questions

Pre-assessment

1) Tell me something you have noticed about your own thinking.
2) Tell me something you wonder about your own thinking or about thinking in general.
3) Tell me something that has changed about your thinking since kindergarten.

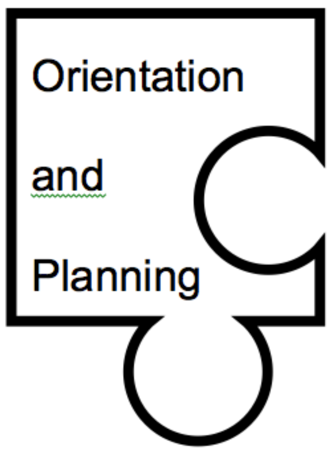
Post-assessment

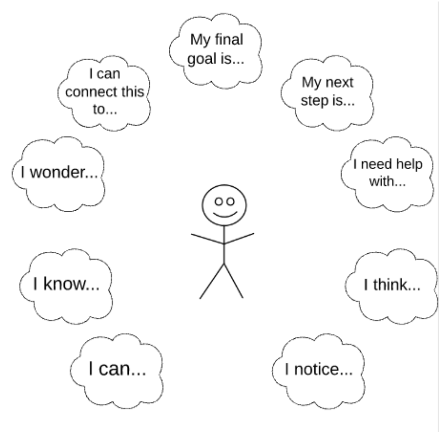
1) Tell me something you have noticed about your own thinking.
2) Tell me something you wonder about your own thinking or about thinking in general.
3) Tell me something that has changed about your thinking since the beginning of our coding unit.
4) Tell me something you have learned about thinking since the beginning of our coding unit.
5) How would you describe "metacognition" in your own words?
6) What was your favourite part of the coding unit? (it doesn't have to be about thinking or metacognition).

## Appendix 3 – Select Written Classroom Tasks: Assignments, Reflections, etc.

This appendix contains select written assignments that students completed.  Some explanations have been added.  Some assignments have altered for sizing, spacing,  or format, in order to best fit into this document.

**Orientation and Planning Page:** This page was handed out along during an introduction into orientation and planning skills.  Following class discussion, tudents wrote questions onto the page first independently, then together with a partner, and finally in groups of four.




Here are some questions or sentences I might use while doing the orientation and planning part of my thinking. (write as many as you can think of.  Use the second side of the page if you need to.  Add more later if you think of them later.)

**Coding journal and planning slip:** These were both completed (on separate days) prior to going to the computer lab, to support students in planning what they would work on during the upcoming block.

Coding Journal # ______

Here is a plan for a new idea I have:

| Some Important Steps | A Picture |
|---|---|
| | |

---

Name: ___________________

Planning ahead for planning

What are some things that might be easier to do if you make a plan first?

- 
- 
- 
- 

**Orientation and Planning Page:** This was handed out after discussing a new program students were to work on. They had been given the instruction to make a program where the player got points for doing something (it could be anything within this broad guideline). This planning page was to help students prepare. (2 pages)

## Orientation and Planning Page

| |
|---|
| What is the essential goal Ms. Mathis gave you for this program? |
| What do you already know that will help you make your program? |
| What do you still need to figure out? |
| What do think you need help with?<br><br>Who can you ask for help? |

| |
|---|
| What do you want your program to do? Describe it with words or draw a picture. |
| List as many steps as you can think of for what you need to do to make your program work. After you have listed the steps, try to put them in order. Write numbers beside them to show what order they go in. |

**Coding Journal:** This journal followed practice on using messages and variable as part of a Scratch program.

# Coding Journal

Write down three things that you figured out about messages (this could be about the butterflies program or about something else to do with messages).

1)

2)

3)

Write down three things that you figured out about variables (this could be about the butterflies program or about something else to do with variables).

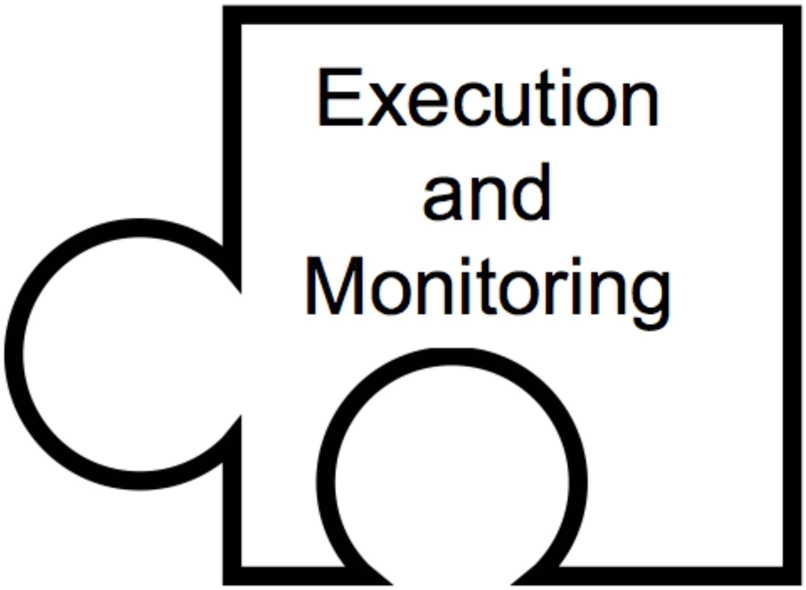
1)

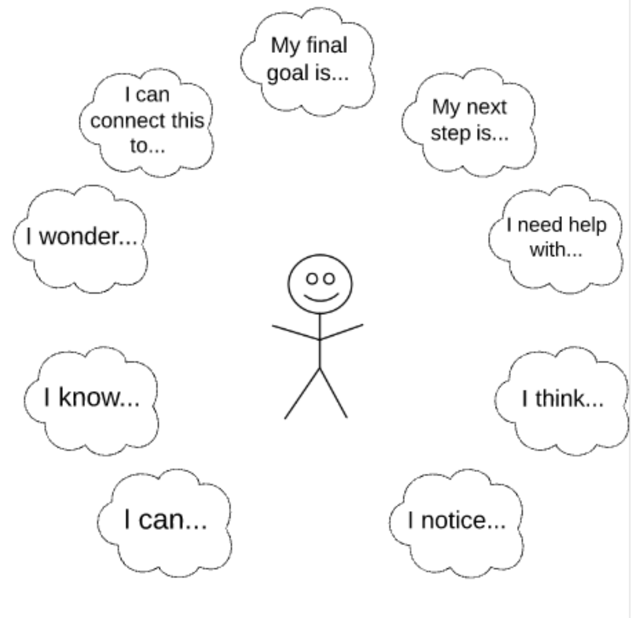
2)

3)

Write or draw some ideas for a program you could create with messages or variables.

**Execution and Monitoring Page:** This page was handed out to students and used similarly as the Planning and orientation page. Using a think, pair, share approach, students added ideas about questions relevant to execution and monitoring.




Here are some questions or sentences I might use while doing the execution and monitoring part of my thinking.
(write as many as you can think of. Use the second side of the page if you need to. Add more later if you think of them later.)

**Debugging Questions and Procedures:** This sheet was given to students following instruction and discussion regarding debugging as metacognitive monitoring. Students referred to this sheet while debugging programs, and added their own ideas onto it.

## Debugging Questions and Procedures

- What is not working the way you want it to?
- What sprites or backgrounds are related to the problem?
- Are there any messages involved? If yes, what sprites or backdrops do they come from?
- Look SLOWLY and CAREFULLY through all of the scripts that affect this situation. What do they do? Think about them in Scratch language, like a list, and like a paragraph.
- Check your starting scripts. Did you make sure everything starts the way you want them to?
- Check your if statements – do they say what you want them to say.
- Check your repeats. Do they need to stop sooner? Do they need to repeat longer? Would a [repeat until] be better?
- Check your variables. What makes them change? Do they make other things change?
- Does anything need to show or hide?
- Do you need to add any [wait] commands? Is there something happening so fast you don't see it?
- What other questions should you ask yourself?

**Coding Journal:** This journal was completed after a coding session.

Coding Journal

Date:________________

Three things I noticed about my thinking today are:

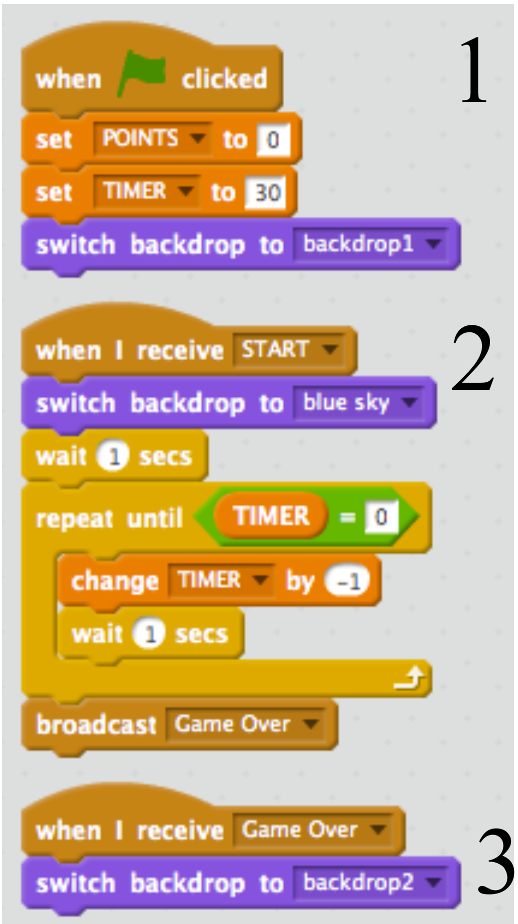
1)

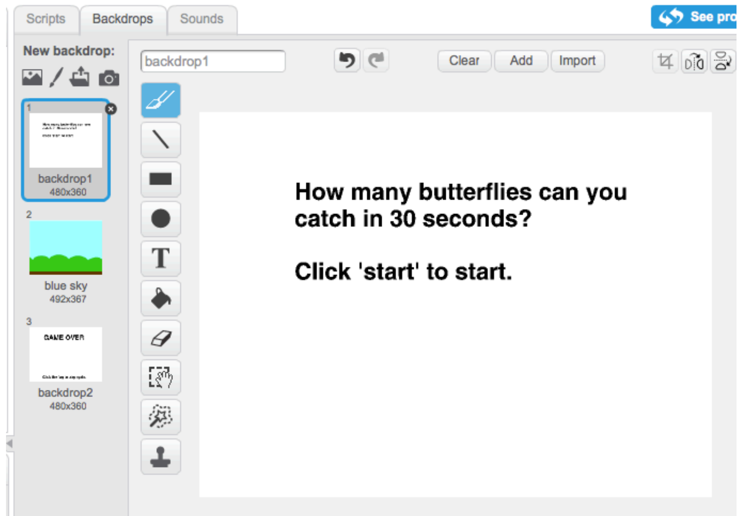
2)

3)

**Debugging Practice:** Students used these sheets to practice debugging, particularly identifying what a script does, and whether or not it will work. (2 pages)

These are all the scripts in the backdrop for the butterfly catcher program:




Describe what each script does:

| Script 1) | |
|---|---|
| In a list: | In a paragraph: |

<table>
<tr><td colspan="2">Script 2)</td></tr>
<tr><td>In a list:</td><td>In a paragraph:</td></tr>
<tr><td colspan="2">Script 3)</td></tr>
<tr><td>In a list:</td><td>In a paragraph:</td></tr>
</table>

**Debugging Practice 2:** Used similarly to previous exercise. (1 page)



This script is in the backdrop for the program:


In regular language, what does the script do?

| In a list: | In a paragraph: |
| --- | --- |
| | |

**Debugging Journal:** This journal was completed after a coding session.

# Debugging Journal

Write about a problem, bug or glitch that you had to debug today.

1) What was the program supposed to do?

2) What did it do instead?

3) What did you change to fix it?

4) How did you figure out what you had to change?

**Mini-Project:** This assignment was to support students in practicing to use the arrow keys, and to show their thinking about debugging. There was a second page to the comic strip. Also, I had drawn by hand a head with thought bubbles on the comic strips. A similar comic strip was used later. See the results section for what the comic strips looked like with the hand drawn part added. (2 pages attached)

## Mini-Project

Make a program that uses the arrow keys to make a character walk around the screen and collect food (for example, a bunny walking around to collect chocolate eggs). Every time the character collects a piece of food, it grows bigger. Make it so the game goes on forever (more food keeps appearing in different places after the character gets the food in one place), until the character is too big to move on the screen. You can choose whether the food moves around or not, and any other features you want to add. Try to make the game work really well without any glitches.

After you finish, think about one problem you had along the way. Fill out the comic strip on the back of this page to show your thinking while solving this problem. Each thought bubble must use one of the sentence starters below. You can use each sentence started a maximum of two times. You don't have to use them all. When you're done, add facial expressions and draw what you might see on the computer screens.

Sentence Starters:

- I think…
- I wonder…
- I notice…
- I need to…
- I can't…
- I can't…
- I know…
- I know how to…
- ___ is connected to ___
- The reason for ___ is ___
- I'm looking at…
- My final goal is…
- My next step should be…

**Commenting Sheet:** This sheet was to support students in commenting meaningfully, connected to collaboration and evaluation skills. This was explicitly taught through a lesson including samples of comments.

Commenting on your Classmates' Programs

**Good comments:**

- are respectful and positive
- use "I" statements
- are specific – Instead of "good job" talk about something specific that you like.
- are constructive – You can give suggestions to fix bugs or improve the program, but make sure it's worded in a way that is helpful and not hurtful.
- end on a specific compliment or an "I wonder statement".
- sometimes start a good conversation going.

**Example:**

*Cool game! I really like how you made it funny by having the soccer ball say things to the cat to chase it. I found the game a little too hard. I think it might be a bit easier to play if you made the soccer ball a bit slower. The colour changes in your game looked really cool. Your game was really fun to play.*

-----------------------------------------------------------------------------------

**Practice:**

Think of a program that one of your classmates or Ms. Mathis made. Try to write a comment for that program, using the instructions/criteria above.

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

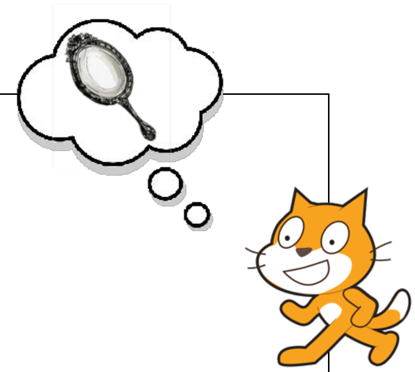
**Scratch Project Planning Sheet:** This sheet was handed out to support students in planning their final project for the unit.

## Scratch Project Planning Sheet

| |
|---|
| My project will be a (circle one): Game Tool |
| Here is a brief description of my project: |
| Some Scratch commands I might need to use in my project are: |
| Here is a picture of what I think my project will look like: |

**Scratch Project Reflection:** This sheet was completed by studdents following creating their program. It was designed to help them practice evaluation and elaboration skills. (2 pages)

# Scratch Project Reflection



Here is a short description of my project:

The first version of my project was like this:

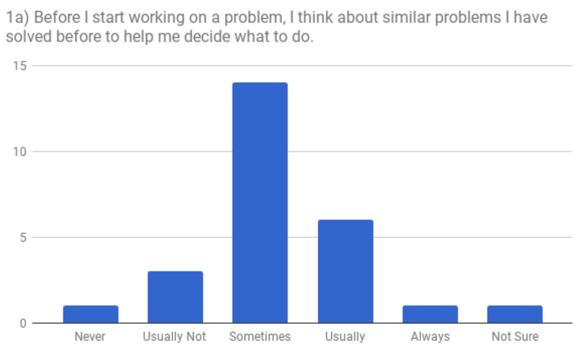
| Description | Picture |
| --- | --- |
| | |

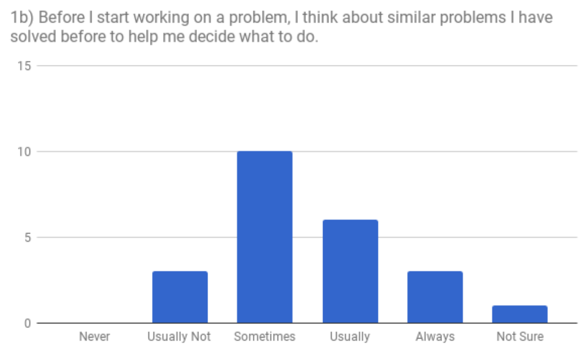
Some changes I made along the way were:

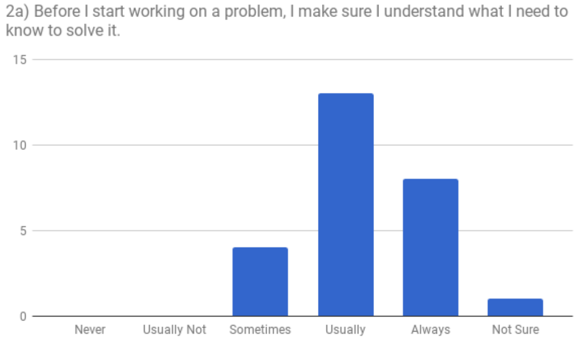
| In the end, my project was like this: | |
|---|---|
| Description | Picture |
| Something I learned while working on my project was: | |
| My favourite thing about making this project was: | |
| One challenge I had to overcome while creating my project was: | |
| My solution to this problem was: | |

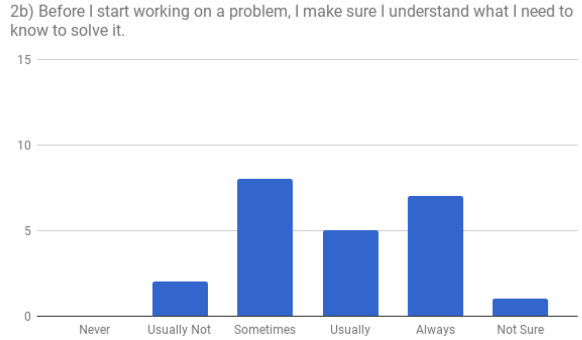
## Appendix 4 – Complete Results for Metacognitive Skills Inventory Multiple-Choice Questions

| Pre-Assessment | Post-Assessment |
|---|---|



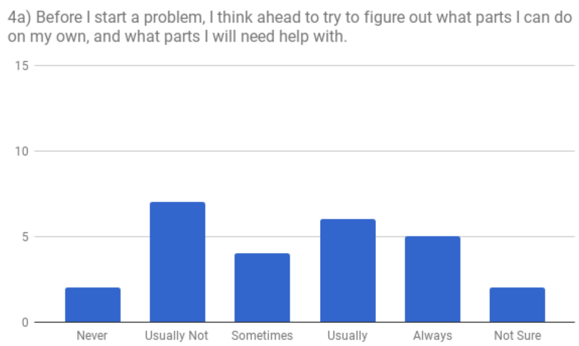



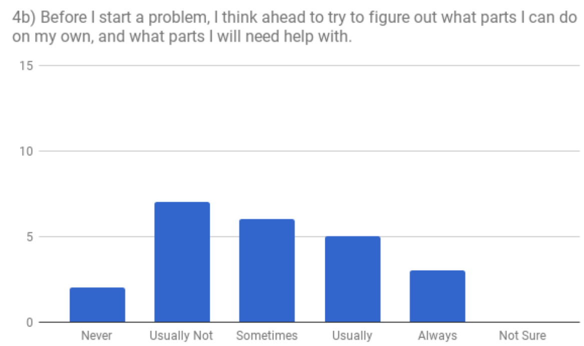



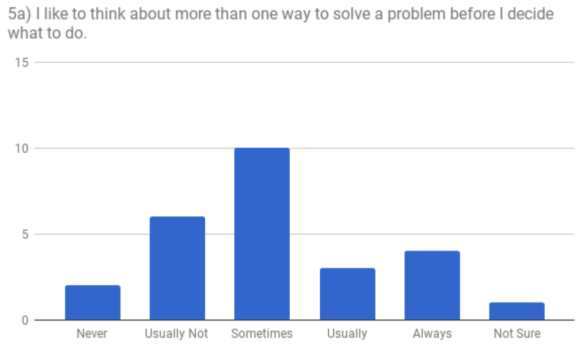


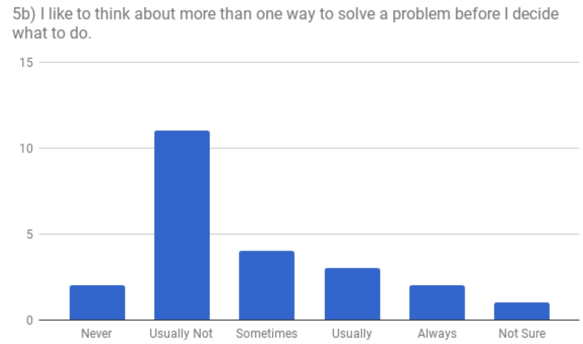
Pre-Assessment

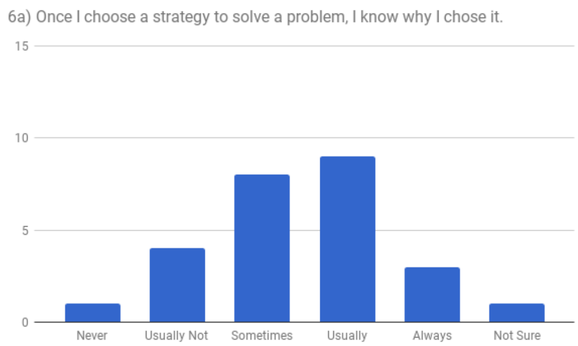
Post-Assessment

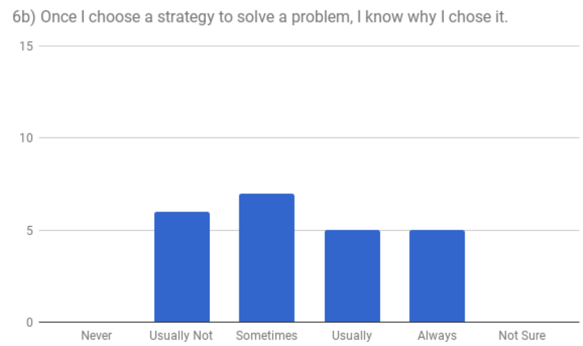


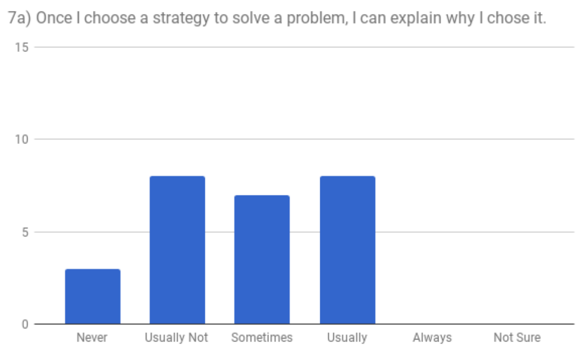



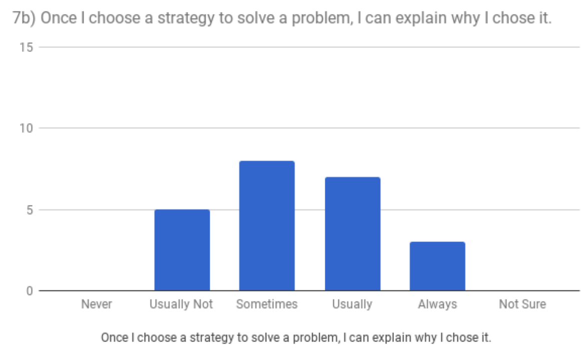



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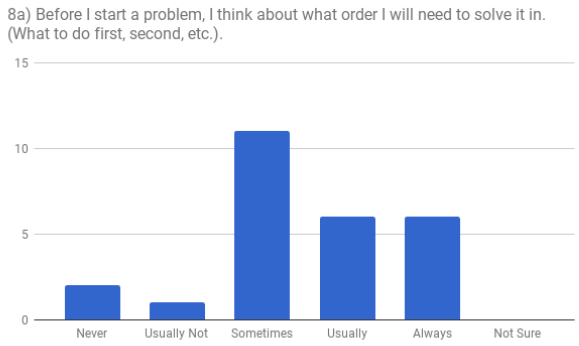
|  |  |
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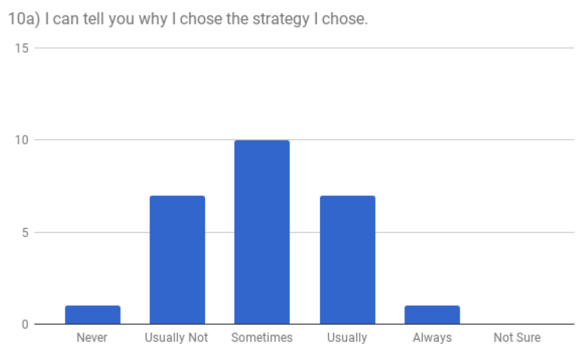
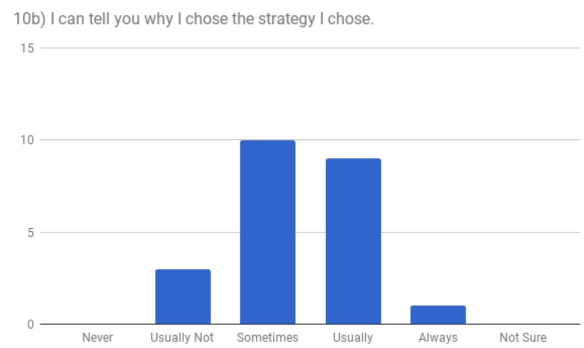
|  |  |
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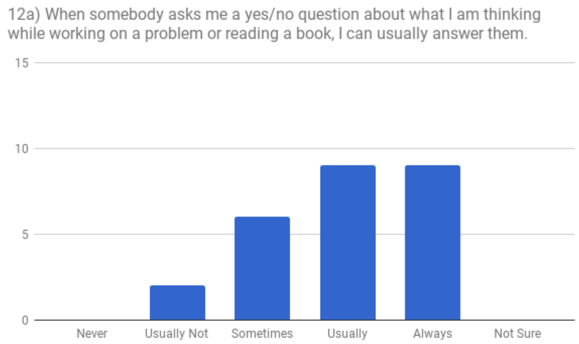





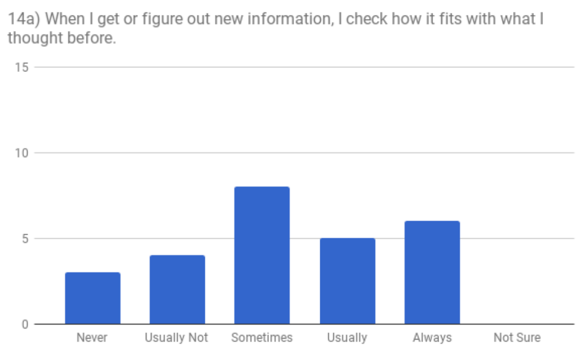


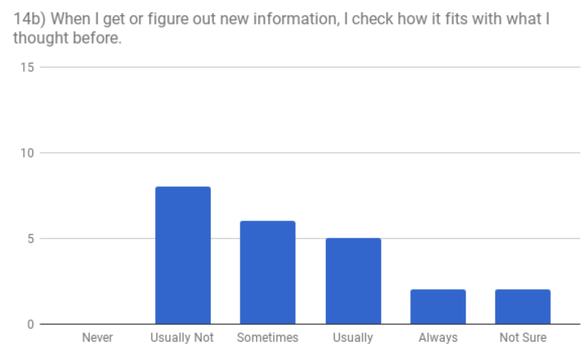


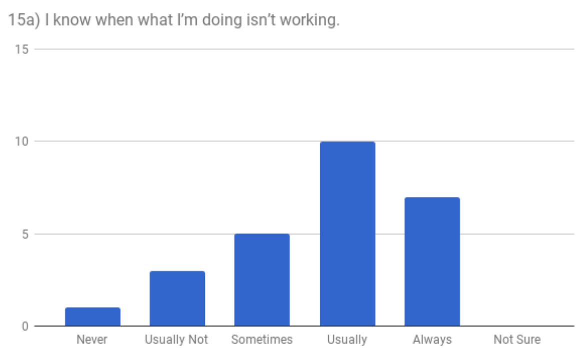


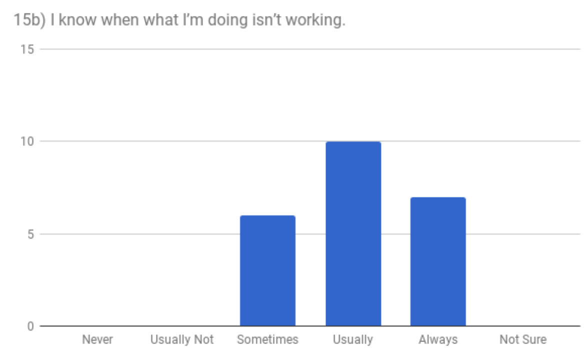

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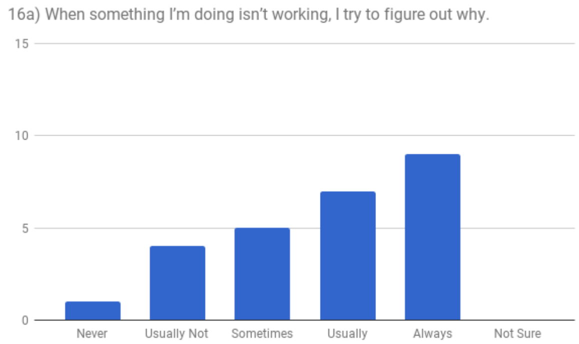
<tr><td>
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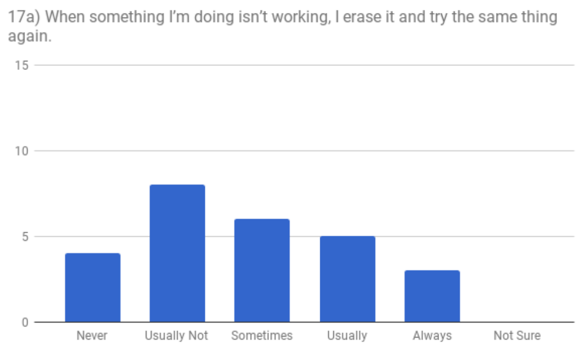
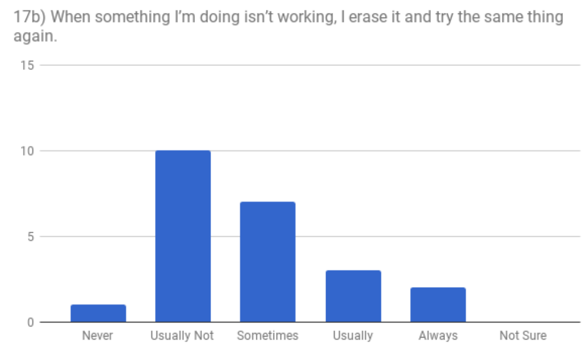
<tr><td>
</td><td>
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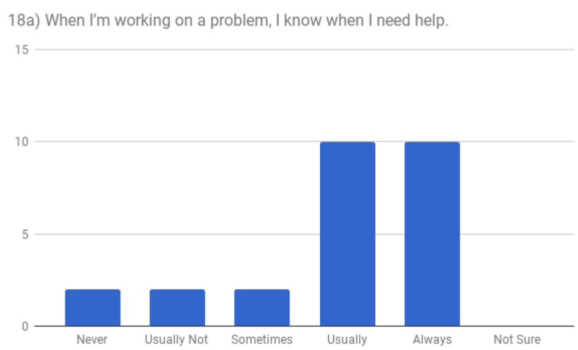
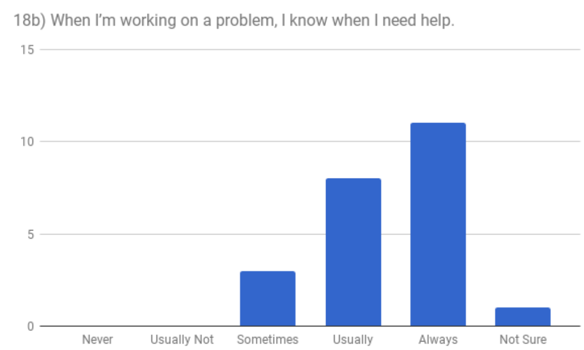
<tr><td>
</td><td>
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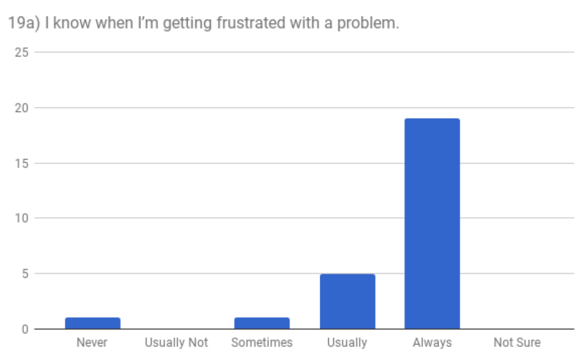
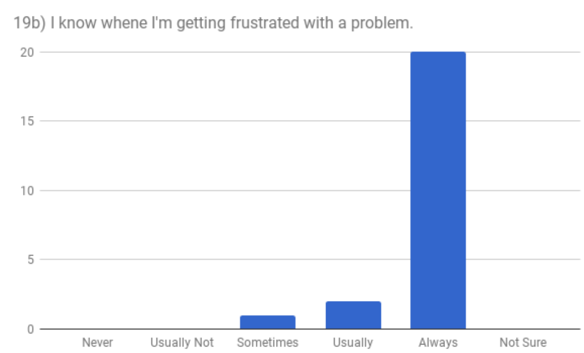
<tr><td>
</td><td>
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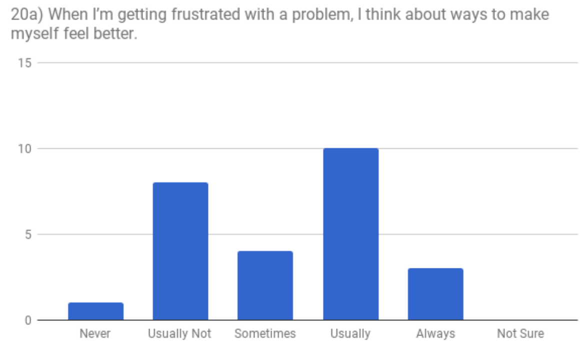
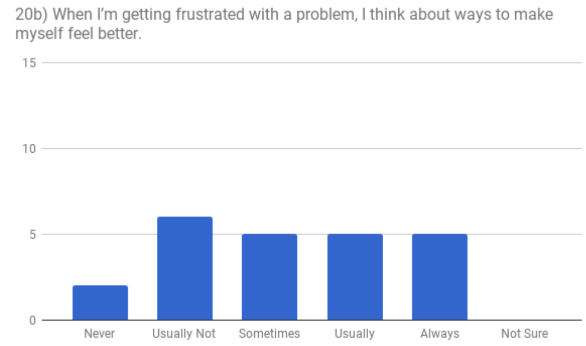
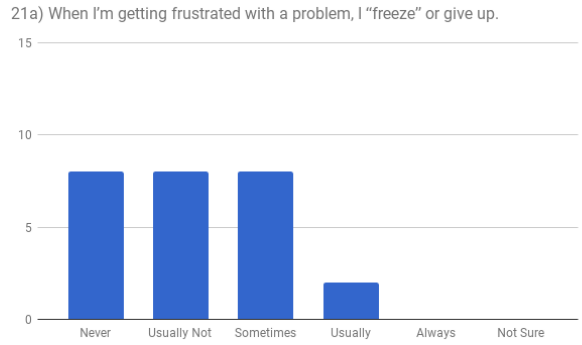
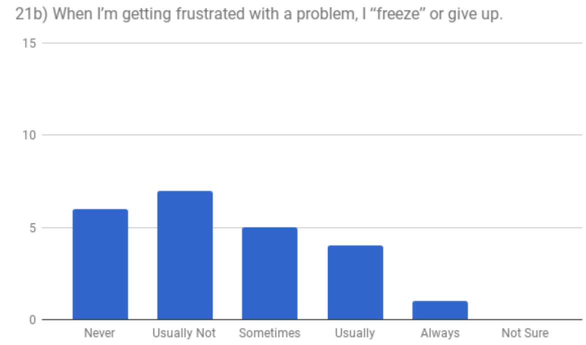
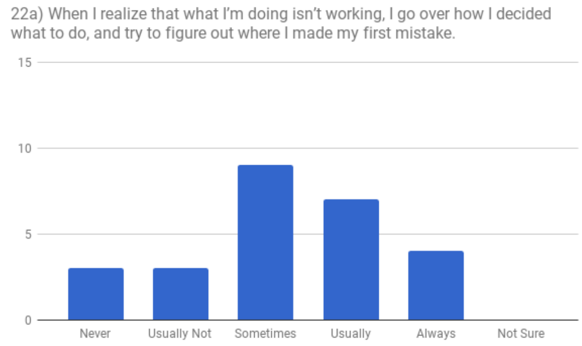
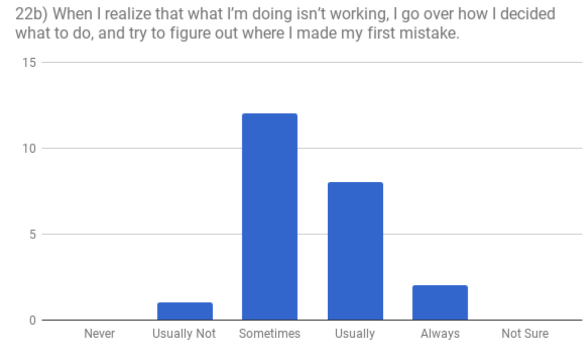
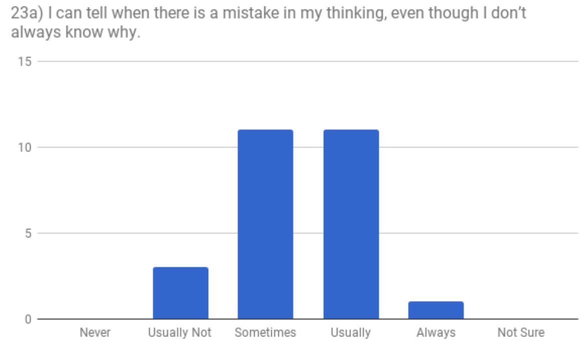
|   |   |
|   |   |
|   |   |
|   |   |

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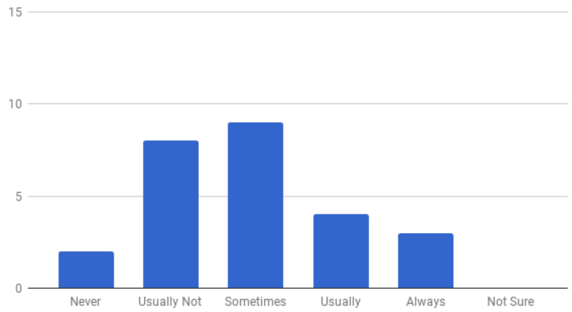

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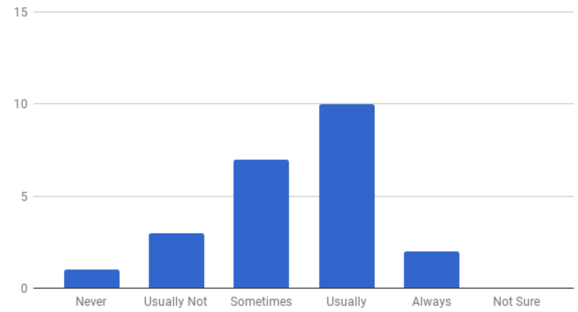
24b) After solving a problem, I can explain how I did it.



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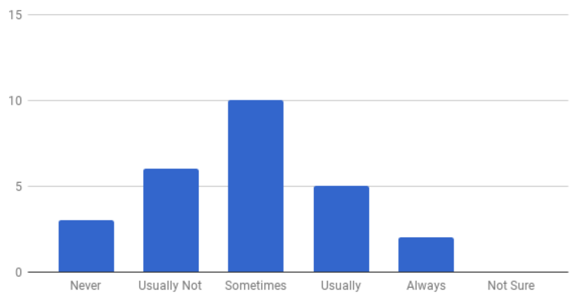
25a) After solving a problem, I can think of other situations where a similar solution might be helpful.



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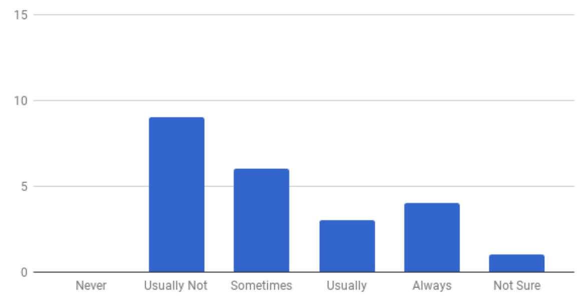
25b) After solving a problem, I can think of other situations where a similar solution might be helpful.



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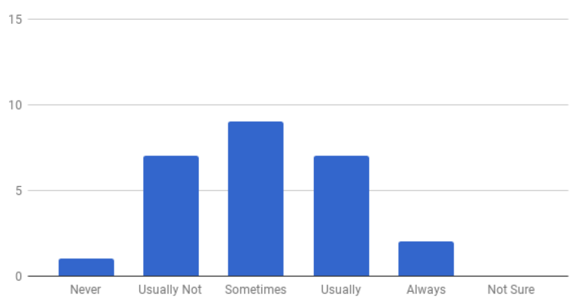
26a) After doing a lesson or an assignment, I can tell you what changed about my knowledge and thinking from before the lesson or assignment.



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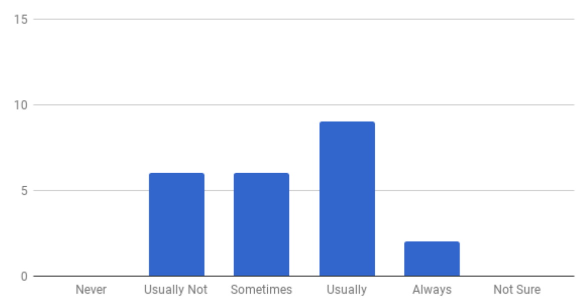
26b) After doing a lesson or an assignment, I can tell you what changed about my knowledge and thinking from before the lesson or assignment.



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27a) When I get stuck, or when I don't succeed at a problem or at part of a problem, I think about what I need to learn to succeed next time.

</td><td>
27b) When I get stuck, or when I don't succeed at a problem or at part of a problem, I think about what I need to learn to succeed next time.

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## Appendix 5 – Transcripts of Think-Aloud Assessments

Students recorded each other thinking aloud using iPad® mobile digital devices. Students recorded what the person was saying, as well as the screen they were operating. Videos cannot be shared here, because many students also filmed the faces of the student recording, and because names were used. These transcripts reflect what was said, and some additional information about what the student was doing or what was on the screen. These transcripts are for the three think-aloud assessments discussed in the results.

**S1**

Pre-Assessment TAA

"SO, go here, hm. One, two, three four, right turn, up, left, turn, umm.. forward, pick up, turn, forward, turn, drop. Okay, now I'm going to see if that works. Come on. Come on, you better work… Yay! I got it!"

Post-Assessment TAA

(teacher reminds to think out loud) "ok. So, I have to get up when I land on that. So I'm going to turn right, up, left, left up. Then I'm going to here – up, up, right, up, up, up, up, up. And then I'll try that out now. I just did it random, I guess, because I'm going up the hill. (watching the program run) – Up, up, up.. No, I think that's too many ups. Actually, yeah.. No! I needed one more up. (programming again) So, after that turn… so I now I'm going to shoot the ball to go up there.. And then I'll go up, up, turn, up, up, there.. I'll pick up, then I'll go up. So I'll go there, and then up, and then go up, and then I'll just drop it. So I hope this works.. oh my gosh.. (watching it run again) – Yes! Come on – get up, up, up, up, up.. now this should hopefully work.. Let's see if I shoot it… They've programmed it to stop everything.. So I guess when I pick it up, that will probably stop it, and that will make it work… Yay!"

**S2**

Pre-Assessment TAA

"You're about to see something extremely awesome! Ok.. turn, turn, straight, turn, left, umm.. straight, pick up, and then left, then go straight, left, straight, drop, so… (watches program not work) - I'm sorry for ruining the phenomenon right here, um.. (works in silence for a while). Straigh, go, turn, right here, take that out, then here go straight. No, I'll clear it. One, two, three, four, turn, straight, turn, straight, turn, straight, pick up. So, after that you pick up and go straight, you go straight, straight, drop. Ok.. So.. Yeah! Pick up, then straight, turn, straight.. Oh! But let me do it again. What the heck? Why did he just back up? Sorry. (reviewing program) Ok, turn, turn, straight, turn, pick up.. Ok, this is what I did (watches program run) – straight, forward, straight, and then you turn, and then turn again, and then straight, pick up.. oh. Oops. (back to programming). Take this out.. Ok, so, I did that, turn, pick up, ok. And then before you turn… oops. (works in silence for a while). Come on! This has to work! [Says friend's name] – this ain't working. (friend offers to help). No, ok, I got this. This will work, [friend], I promise. If it doesn't you can take over. No! (fixes something), and then after that you turn! Ok! Uh huh! Got it!"

Post-Assessment TAA

(teacher reminds to think out loud) "So, (showing motion using hands, but not programming yet) go straight, then pick it up, and then turn around, so then I'll go here, straight, turn, and then go back straight, and then pick it up. Then, see if this will work. Ok, go straight again, then you turn and then you drop it. Oh wait, that was one step too much. Take this out, then try again. OK, you turn around maybe once, no, twice. Then you go straight, then you turn, then you drop it."

**S3**

Pre-Assessment TAA

"Go forward, pick up, right, drop, go, right, go, left, go, right, go, left, conveyor, pick up, rotate, twice, drop! Literally. That is what I am thinking. Yes!"

Post-Assessment TAA

"so, one, two, three; (teacher reminds to think out loud) so, my thinking is that, well, hmm, let's see… No, no, no, I need to calculate this because there's this gap here. I wonder how this gap even works. (thinks quietly for a while, and adds dome code). I have to test this step by step, and it gets awkward when I am thinking aloud, but I just do this step by step. So… so, after all, I just like doing stuff step by step and a bit slowly. Just in case. Because I just want to be extra cautious. So, I know that I could drop it into that blue tile. And once I enter there I need to wait two turns… This is really confusing. I'm saying what I'm thinking. This is honestly very confusing. (teacher reminds to just do best) If I were to say my thinking out loud right now, then (makes comment about appearance of game). And I just think… I think it's strange that I even bothered to wait. Oh. I made such a terrible mistake. Agh! Come on! I don't think I'm adding two and two together while I am doing this to be honest. I actually don't think that. Maybe, uh, this is getting way too confusing. (continuing to try out different ideas) I wonder how is this level completable anyways. I have to hit this target! Agh! I doubt this level is completable. I honestly highly doubt that this level is even possible. Or is it just that the creators of the game are trying to create more levels, so this level will be impossible? I don't know. Yeah, it's so confusing. Just hard to decide whether or not to do these stuff or not. So, everybody has a different way of doing this, and I personally, uh, I have to think again about doing this part. I'm not sure if this level is completable. There's a big gap here. But if it's not completable, then why is this a level? Probably because it is completable by secret or something. (friend who is filming makes a small suggestion, then student continues talking) Oh, yeah, the target makes the conveyor move. Theres a bunch of hidden targets in the game as well. I didn't really ever realize that. This is so annoying when this happens. So annoying. I just don't really like it. It just happens, um… maybe, one, two, three (counting blocks of code)… turn, go, then drop? I can't – this gap is so confusing. Seriously. This gap is so confusing. I wonder how this gap works. I wonder if there is something invisible there, because I dropped the green crate thing in that gap before. And I wonder if there will ever be more levels. I guess it depends on the last cut scene after this impossible level. This is so time consuming! If only there was some kind of a – I don't know – speed up button? There is a reason why there's probably no speed-up. Hey, I wonder what happens if I shoot the ball while holding that crate thing. (tests it out) Oh no! What the? (looks back over code, and makes small change) Maybe like that? I wonder… I honestly wonder… I think this robot needs two hands to hold onto the crates. There has to be a way to get it past that gap. Unless if they're planning – unless if the developers are planning to make a sequel or something. Ok, now I don't know why I'm even thinking that. It doesn't make sense. There has to be a quicker – I think there should be a quicker way to do this. I think this should work. Well, I haven't shot out a ball with a crate before. Guess I'll never know until it really happens. (friend comments on this thought). (back to S3). (waits for program to run, sees what happens with the idea). Woah! Wait, what? It didn't work?! Ok, if this doesn't work, then this level is impossible. There's actually, I wouldn't want to see the awkward falling animation again. Hey, wait a minute! Did I miss something? If I couldn't drop it there, then – wait a minute! Couldn't I just drop it there?! (points to other place). I wonder, if it's possible to just drop it over there. If the robot falls this time, then it is definitely supposed to be dropped over there. If the robot falls… But the conveyor isn't really over here, so that's got to be the solution of the level, if this doesn't work. I just put three extra waits, just in case. Which is exactly how many waits I actually need to do…. This is so confusing! (thinks for a few seconds). Ok, now I know the solution to the level. Let's see… I made a terrible mistake. (checks over code) One, and drop… Wait, wait, wait… This has got to work! This would be so sad if it doesn't work. So, if it does work, then I would be wasting a lot of moves that time. This is so frustrating! I've definitely seen that CPU thing on that robot before. Yup, I made a terrible mistake. I could have saved a lot of moves. I'll probably get zero stars for this, but that should be ok. I think that you could actually shoot while holding a crate. I could have just done it the simpler way. I guess that I don't want to do it simple. Oh! It works! I'm doing.. Yay!! I did it!"