DEPARTMENT OF CURRICULUM & PEDAGOGY
THE UNIVERSITY OF BRITISH COLUMBIA

EDCP 585B (951): Science and Mathematics Teaching and Learning through Technologies

Course and Instructor Information:

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UBC, 2125 Main Mall, Vancouver, B.C., V6T 1Z4
Course: EDCP 585B Section 951
Meeting time: July 21 – August 8, 2014, Monday – Friday 10:30 am – 1:00 pm
(Suggested change: to meet 9:30 am – 1:00 pm July 21- August 1, final paper submission – August 8th)
Room: Scarfe 1210

Course Description and Goals:

In the 21st century, students' abilities to grasp complex math and science[1] concepts, collect and analyze real time data, make sense of the data-rich information and conduct independent investigations have become increasingly important. At the same time, rapid advances of our knowledge of how people learn STEM disciplines coupled with the ever growing range of modern educational technologies allowed contemporary educators to have an unprecedented range of opportunities to engage their students in meaningful learning. These trends have significantly affected the teaching of STEM and the pedagogical skills required of contemporary teachers, who have to acquire not only the pedagogical and disciplinary content knowledge, but also the knowledge of content-specific educational technologies and relevant pedagogies. **The in-depth exploration of this knowledge (dubbed a Pedagogical-Technological Content Knowledge or TPCK [1, 2]); the process of TPCK acquisition by the STEM teachers; and multiple ways for implementing technology-related STEM education research in the teaching practice is the goal of this course** (Figure 1).

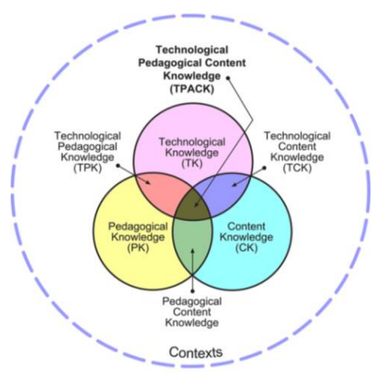

Figure 1: Technological-Pedagogical Content Knowledge Framework: http://www.innovativelearning.com

[1] From now on we will use the term STEM (Science, Technology, Engineering, and Math)

Course Scope: Explore theoretical background and applications for STEM technology-enhanced learning and teaching

In this course, we explore the theoretical background for design, implementation, and the educational impact of different technology-enhanced STEM learning environments, such as:

1) **Peer Instruction** [3] and **PeerWise** [4-6]: design of electronic response systems (clickers) enhanced learning environments [7-10] in STEM [11-13].
2) **Modeling in STEM contexts:** the use of modeling to promote meaningful STEM learning (i.e., Geogebra; Geometer's Sketchpad, and video-analysis) [14-17].
3) **Real-time data collection and analysis:** the use of probe ware to acquire real time data to test science hypotheses and construct STEM understanding (i.e., Logger *Pro*) [18-24].
4) **Computer simulations and data visualization**: the use of simulations to conduct virtual investigations, simulate STEM problems and test ideas (i.e., PhET) [25-28].
5) **Math and science games and video games** as a tool to develop critical thinking [29].

Course participants will conduct a relevant literature review and develop criteria for evaluating technology-enhanced STEM activities, their pedagogical sustainability and impact on student learning. In order to link the theory to practice, the students will apply these criteria for designing and evaluating their own technology-enhanced STEM educational experiences that foster active inquiry and meaningful understanding: an Educational Technology Exploration paper (theoretical analysis) and an Educational Technology STEM Lesson/Unit/Workshop/Lab Design Project (practical application). The Project will be an example of a technology-enhanced pedagogical intervention that will (a) allow the students to apply their theoretical knowledge to practice in their area of interest; (b) include an analytic rationale component, a practical design and an evaluation for sustainability and pedagogical effectiveness; (c) be presented and peer evaluated by the course participants. As part of the course, every course participant will be asked to provide oral and written feedback to their classmates. The course is intended as a graduate seminar and will require a rigorous level of intellectual engagement on behalf of the participants and ability to apply theoretical knowledge to classroom practice.

Course Delivery (content areas and tentative schedule)

Content Area 1: How People Learn – A case for technology (Week 1: July 21st - 25th, 2014)

Meetings 1-5: We begin the course with exploring the implications of learning theories such as behaviorism, cognitivism, and constructivism on STEM education.

Meetings 1-2: Learning theories and their applications on design and implementation of effective STEM technology-enhanced learning environments

Critical question: How should our knowledge of STEM learning affect the design and implementation of technology-enhanced learning environments?

Key readings and online resources: 1, 3 are the required readings for the course; 4 is a very interesting project; 5 – an inspirational video on science teaching and learning.

1. Bransford, D., Brown, A. L., & Cocking, R. R. (2002). *How people learn: Brain, Mind, Experience, and School*. Washington, DC: National Academy Press. (Free online: http://www.nap.edu/openbook.php?isbn=0309070368)
2. Donovan, M. S., & Bransford, J. D. (Eds.). (2005). *How Students Learn: History, Mathematics, and Science in the Classroom*. Washington D.C.: Division of Behavioral and Social Sciences and Education, The National Academic Press. (Free online: http://www.nap.edu/openbook.php?record_id=10126&page=1)
3. Brown, G. (2004). How Students Learn: A supplement to the RoutledgeFalmer Key Guides for Effective Teaching in Higher Education series**:** 50.
4. A Private Universe Project: http://www.learner.org/teacherslab/pup/ (A very revealing investigation of how students learn science… and how we teach it…)
5. Mazur, E. (Producer). (2010, February 24, 2011) Confessions of a Converted Lecturer. Video archive retrieved from http://pirsa.org/10110081/
6. Mazur, E. The Tyranny of the Lecture presentation http://blogs.ubc.ca/mmilner/2013/06/28/eric-mazurs-lecture-the-tyranny-of-the-lecture/

Meetings 3-4: Inquiry-based STEM education – a case for technology integration

Critical question: How can technology support inquiry-based STEM education?

Key readings: Must read - 1, 2 and 4; 3 is a good reference and explore references 5.

1. Papert, S. (1980). *Mindstorms: Children, Computers and Powerful Ideas*. New York: Basic Books, Inc., Publishers. (Available online: http://www.arvindguptatoys.com/arvindgupta/mindstorms.pdf)

2. Lee, H.-S., Linn, M. C., Varma, K., & Liu, O. L. (2010). How Do Technology-Enhanced Inquiry Science Unit Impact Classroom Learning? *Journal of Research in Science Teaching, 47*(1), 71-90.
3. Hew, K., & Brush, T. (2007). *Integrating technology into K-12 teaching and learning: current knowledge gaps and recommendations for future research*. Educational Technology Research and Development, 55(3), 223-252.
4. Hoyles, C., & Noss, R. (2008). Next steps in implementing Kaput's research programme. *Educational Studies in Mathematics, 68*(2), 85-97.
5. Powers of Ten: http://www.powersof10.com/ an online resource for mathematics teachers (based on the film by Charles and Ray Eames).

Class 5: Development of critical thinking in the technology-enhanced STEM classroom

Critical question: How can technology be used to support the development of critical thinking in STEM?

Key readings: 1, 2 and 4. Reading 3 focuses on STEM teacher education with technology.

1. Healy, L., & Hoyles, C. (1999). Visual and Symbolic Reasoning in Mathematics: Making Connections with Computers? *Mathematical Thinking and Learning, 1*(1), 59-84.
2. Finkelstein, N. D., Adams, W. K., Keller, C. J., Kohl, P. B., Perkins, K. K., Podolefsky, N. S., et al. (2005). When learning about the real world is better done virtually: A study of substituting computer simulations for laboratory equipment. *Physical Review Special Topics - Physics Education Research, 1*(1), 010103.
3. MacDonald, A., Milner-Bolotin, M., Fisher, H. (2014). Using Technology for Conceptual Learning in Physics Teacher Education: Engaging Teacher-Candidates as Learners and Teachers. American Educational Research Association Annual Conference. Philadelphia, PA, American Educational Research Association**:** 30.
4. Milner-Bolotin, M. and S. Nashon (2012). "The essence of student visual–spatial literacy and higher order thinking skills in undergraduate biology." Protoplasma **249**(1): 25-30.

Content Area 2: Technology Implementation in STEM Classrooms (Week 2: July 28th – August 1st, 2014)

Meetings 6-9: We will narrow down our exploration to specific educational technologies and discuss the key elements of technology-enhanced pedagogies in STEM contexts. One of the main foci of our investigation will be the development of teachers' Technological-Pedagogical Content Knowledge (TPCK).

Meetings 6-7: Contemporary educational technologies in STEM

Critical questions: What are the strength and weaknesses of modern educational technologies for STEM teaching? Why would you choose or not choose to use them in a science or mathematics classroom and how would you convince your colleague to do the same?

Key readings: 1, 2, 4 and 6; you can replace any two of these readings by the relevant reading of your choice.

1. Beatty, I.D., et al., Designing effective questions for classroom response systems teaching. *American Journal of Physics*, 2006. **74**(1): p. 31-39.
2. Campbell, T., Wang, S. K., Hsu, H.-Y., Duffy, A. M., & Wolf, P. G. (2010). Learning with Web Tools, Simulations, and Other Technologies in Science Classrooms. *Journal of Science Education Technology,* **19***:* p. 505-511.
3. Dugdale, S., *The design of computer-based mathematics instruction*, in Computer assisted instruction and intelligent tutoring systems: Shared issues and complementary approaches, J.H. Larkin and R.W. Chabay, Editors. 1992, Erlbaum: Hillsdale, NJ. p. 11-45.
4. Gee, J.P., Learning by Design: good video games as learning machines. *E–Learning*, 2005. **2**(1): p. 5-16.
5. Milner-Bolotin, M. (2004). Tips for Using a Peer Response System in Large Introductory Physics Classroom. *The Physics Teacher*, **42**(8): p. 47-48.
6. Milner-Bolotin, M., et al. (2013). "Modeling active engagement pedagogy through classroom response systems in a physics teacher education course." LUMAT: Research and Practice in Math, Science and Technology Education **1**(5): 525-544.

Meetings 8-9:

Critical questions: What are the strengths and weaknesses of 3 modern educational technologies of your choice? Why would you choose or not choose to use them in a science or mathematics classroom and how would you convince your colleague to do the same?

Key readings: 2, 3, 5 you can replace any two of these readings by the relevant reading of your choice

1. Antimirova, T., & Milner-Bolotin, M. (2009). A Brief Introduction to Video Analysis. *Physics in Canada*, **65** (April-May): p. 74.
2. Milner-Bolotin, M., A. Kotlicki, and G. Rieger. (2007) Can Students Learn from Lecture Demonstrations: The Role and Place of Interactive Lecture Experiments in Large Introductory Science Courses. *Journal of College Science Teaching*, **36**(4): p. 45-49.
3. Hohenwarter, J., Hohenwarter, M., & Lavicza, Z. (2008). Introducing Dynamic Mathematics Software to Secondary School Teachers: The Case of GeoGebra. *Journal of Computers in Mathematics and Science Teaching*, **28**(2), 135-146.

4. Sinclair, N., & Yurita, V. (2008). To be or to become: How dynamic geometry changes discourse. *Research in Mathematics Education*, **10**(2): p. 135-150.
5. Wieman, C. E., Adams, W. K., Loeblein, P., & Perkins, K. K. (2010). Teaching Physics Using PhET Simulations. *The Physics Teacher,* 48(April), 225-227.

Content Area 3: Development of Mathematics and Science Teachers' Technological-Pedagogical Content Knowledge (Week 3: August 3rd - 8th, 2014)

Meetings 10-11: We will focus on the development of STEM teachers' Technological-Pedagogical Content Knowledge (TPCK) and explore how teachers can be supported in technology implementation.

Meeting 10: Development of Technological-Pedagogical Content Knowledge

Critical questions: What is TPCK and how is it be supported and developed in STEM?

Key readings: 1, 4. Make sure to read Shulman's paper!

1. Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education*, **9**(1): p. 60-70.
2. Koehler, M. J., & Mishra, P. (2005). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research*, **32**(2): p. 131-152.
3. Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record*, **108**(6): p. 1017–1054.
4. Shulman, L. S. (1986). "Those who understand: Knowledge growth in teaching." Educational Researcher **15**(2): 4-14.

Meeting 11: Professional development for STEM teachers: supporting teachers' TPCK

Critical question: What are the key elements of effective Pro-D design and imlementation?

(Key readings –1-2**)**

1. Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, **21**: p. 509-523.
2. Varma, K., Husic, F., & Linn, M. C. (2008). Targeted Support for Using Technology-Enabled Science Inquiry Modules. *Journal of Science Educ. Technology*, ***17***: p. 341-356.
3. Please review the projects of students from ETEC 533 2013 course: http://blogs.ubc.ca/mmilner/2013/08/04/educational-tutorials-from-etec533-course/

Course Assessment

A	Active participation	Required
B	Ed Technology Debaters	10%
C	Student-led in-class discussion	20%
D1	Learning and Teaching STEM with Technology Paper	25%
D2	Learning and Teaching STEM with Technology Paper Peer Feedback	5%
E1	Educational Activity STEM Design Project - Draft	15%
E2	Educational Activity STEM Design Project – Peer Feedback	5%
E3	Educational Activity STEM Design Project – Final version	20%

A. Class participation – No grade

Active participation is expected. While no grades are allotted for attendance, in order to attain a passing grade, students are expected to attend a minimum of 80% of classes (12 meetings).

B. Educational Technology Debaters – 10% (5% per debate – 2 debates)

Educational Technology Debaters focus on discussing pros and cons of different educational technologies. Every student will be asked to participate twice as a pro and con educational technology expert. You will have a maximum 3 minutes to express your ideas pro or against a specific educational technology. You will need to find a partner for each one of the debates and choose your role (pro or con). We will evaluate the debates collectively using clickers. Every participant will be able to choose the educational technologies he/she will be debating.

C. Student-led in-class discussion (one) – 20%

You will be asked to lead an in-class discussion on one of the selected readings (the reading choice has to be discussed with the instructor). Each discussion will take 25 minutes and will have two students to facilitate it. The students will need to sign up for the discussion at the beginning of the course. The discussion will consist of a 10 minute presentation (as an opportunity to engage the group in a critical discussion of various ideas, themes, issues, etc. raised by the author(s)) and a 15 minute follow up conversation. You are expected to lead a meaningful and engaging discussion that will help the group to make sense of the required readings and think of new ideas and possibilities. You should be open for questions from your colleagues. Particularly important in this discussion are the links between these readings, personal experiences and other issues previously discussed in this course or in other courses.

D1. Learning and teaching STEM with technology Paper – 25%

Due: Meeting 10

You are asked to submit an Analytic Educational Technology Exploration Paper (up to 2,500 words excluding references) that expands on class discussions about the implementation of educational technologies in STEM classrooms. You might choose to write a paper on the topic you facilitated however, it is not required – any course relevant topic might be chosen. The paper should invoke pertinent literature, a clear issue formulation, which should stem from the rigorous analysis of the assigned readings and your personal experiences and it should offer possible ways of addressing the problems raised or ways of finding the solution. In addition, please provide a brief reflection on how these ideas may impact your own teaching or research. The paper should be submitted electronically via UBC Connect (Assignment menu) either as a pdf or a Word file. You should start thinking about this paper from the very beginning of the course. The marking rubric for the paper is posted below.

D2. Learning and teaching STEM with technology – Peer Feedback – 5%

Due: Meeting 8

You are asked to find a partner, read each other's Analytic Paper and provide detailed feedback. This will get you on the way to becoming a peer reviewer of scholarly work. You will submit this feedback (comments in the Word or PDF file) to your partner and will upload it to Connect so I can read it as well. You will be evaluated by your partner and by me for the quality of your feedback. You will be asked to provide this feedback two days BEFORE the final paper is due.

E1. Educational Technology STEM Activity Design Project – Draft – 15%

Due: Meeting 12

As a summary assignment, you are asked to design a STEM activity, lesson or a lab that will use a technology of your choice. You should focus on particular skills and concepts that you want students to acquire as a result. Imagine that your proposed activity will be used to convince your colleagues that the technology your chose is beneficial for student learning. This activity should have a rationale that will include relevant literature, overview of your goals, the description of the technology and the justification why you chose it. It should follow with the description of activity from the student's perspective, a description of activity from the teacher's perspective, and the means of evaluating if student outcomes you set to achieve had been achieved. While I do not want to force a specific format of the activity on you, I am asking you to think of it as something that you will be able to take to your colleagues or to a STEM Teachers Conference. Notice, the first draft of the activity should be ready by Meeting 12, so you can give it to your peer and me for feedback. You can pair up with the same person you worked earlier or find another partner. For possible ideas check PhET web site: http://phet.colorado.edu/en/simulations/category/new and look don't hesitate to explore the work of your fellow students in my past courses: http://blogs.ubc.ca/mmilner/2013/08/04/educational-tutorials-from-etec533-course/

E2. Educational Technology STEM Activity Design Project – Peer Feedback – 5%
Due: Meeting 13

You will be asked once again to pair up with a classmate and provide each other with a detailed feedback on the activity you designed. Please submit your feedback through Connect so I can read it, as well as e-mail it to your partner. In addition to the written feedback, you are encouraged to discuss it in person. Thus, each one of you will get feedback from me, as well as from at least one of your colleagues before you focus on the final version. Due to the condensed nature of the course, you will have only one day to provide this feedback.

E3. Educational Technology STEM Activity Design Project – Final Activity – 20%
Due: Meeting 15

The final activity should incorporate all the feedback you have received. It will be due on the last day of class. Its format should be negotiated between you and the instructor.

Format of Written Assignments

Written Assignment 'D' should not exceed the word limit. All text should be double-spaced, Times New Roman 12 point or equivalent. Please follow conventional academic format and style and include references (please use A.P.A. guidelines: http://www.okanagan.bc.ca/Page10234.aspx). Ensure that documents are coherent, thoroughly spell-checked and checked for grammar, punctuation and other errors. Assignment 'E' will have a more flexible format as it will depend on the activity you will be descitning.

Policies for Absences & Late Assignments

Absences: Students are expected to attend and actively participate in **all classes**; however, there are times when this may not possible. If a student is going to be absent, it is their responsibility to notify the instructor via email at least 24 hours prior to the start of class. Please check the UBC Attendance policy that outlines what are considered 'unavoidable' absences.

Late Assignments: Students are expected to hand all work in on time. Papers will not be accepted late – you can submit all papers online. For the student led discussion, if a student is unable to attend on the day they are to lead the class in this activity, they must notify the instructor at least 24 hours ahead (again, check the UBC Attendance policy for 'unavoidable' absences) and then work out an alternative arrangement with the instructor once they have returned to class. In the case of a medical illness, a medical certificate may be required.

Grading Guidelines for Assignments[2]:

A level - Good to Excellent Work

A+ (90-100%): A very high level of quality throughout every aspect of the work. It shows the individual (or group) has gone well beyond what has been provided and has extended the usual ways of thinking and/or performing. Outstanding comprehension of subject matter and use of existing literature and research. Consistently integrates critical and creative perspectives in relation to the subject material. The work shows a very high degree of engagement with the topic.

A (85-89%): Generally a high quality throughout the work. No problems of any significance, and evidence of attention given to each and every detail. Very good comprehension of subject and use of existing literature and research. For the most part, integrates critical and creative perspectives in relation to the subject material. Shows a high degree of engagement with the topic.

A- (80-84%): Generally a good quality throughout the work. A few problems of minor significance. Good comprehension of subject matter and use of existing literature and research. Work demonstrates an ability to integrate critical and creative perspectives on most occasions. The work demonstrates a reasonable degree of engagement with the topic.

B level - Adequate Work

B+ (76-79%): Some aspects of good quality to the work. Some problems of minor significance. There are examples of integrating critical and creative perspectives in relation to the subject material. A degree of engagement with the topic.

B (72-75%): Adequate quality. A number of problems of some significance. Difficulty evident in the comprehension of the subject material and use of existing literature and research. Only a few examples of integrating critical and creative perspectives in relation to the subject material. Some engagement with the topic.

B- (68-71%): Barely adequate work at the graduate level.

C & D level - Seriously Flawed Work[3]

[2] *EDCP Grading Guidelines for Graduate level courses - July 2008*

[3] **NOTE:** For UBC's Faculty of Graduate Studies (FOGS) a final mark below 68% for Doctoral students and below

C (55-67%): Serious flaws in understanding of the subject *material.* Minimal integration of critical and creative perspectives in relation to the subject material. Inadequate engagement with the topic. Inadequate work at the graduate level.

Academic Honesty and Standards

This course is governed by UBC's Standards for Academic Honesty:

> "Academic honesty is essential to the continued functioning of the University of British Columbia as an institution of higher learning and research. All UBC students are expected to behave as honest and responsible members of an academic community."

For more information, visit: http://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,286,0,0

Grading Rubrics for Educational Technology Exploration Paper

Qualities & Criteria	Poor (0-80)	Good (80-90)	Excellent (90-100)
Format/Layout • Text presentation • Text structuring • Requirements of length, font and style are followed *(Weight 10%)*	Follows poorly the requirements related to format and layout.	Follows, for the most part, all the requirements related to format and layout. Some requirements are not followed.	Closely follows all the requirements related to format and layout.

60% for Masters students is the equivalent of a Failing mark.

Content/Information			
Framing the issue: • Clear issue presentation • Clear explanation how it is important to you • The issue is grounded in the course activities and the literature *(Weight 20%)*	The issue is not presented clearly and it is not clear how it is personally relevant and interesting to you. No clear case for the relevance of the issue to the class discussions is made. The issue is not grounded in the course activities and literature.	The issue is presented clearly but it is not clear how it is personally relevant and interesting to you or how it should be of interest to the readers. The issue is grounded in some of the course activities.	The issue is presented clearly emphasizing how and why it is personally relevant and interesting to you or how it should be of interest to the readers. It is grounded in the course activities and literature (i.e., auto-e-ography, video cases, and the interview).
Analyzing the issue: • **Position of the paper** • **Logical and coherent analysis** • **Analysis of the paper from multiple perspectives** *(Weight 20%)*	The position of the paper is not situated within the contemporary discourse. The analysis is lacking breadth and depth.	Paper position is somewhat situated within contemporary discourse. Only one perspective on the issue is identified and the literature analysis is incomplete. Not all key issues/ concepts are identified.	Paper position of is situated clearly within contemporary discourse. Multiple perspectives on the issues are identified. The patterns coming out of the literature are located and main points, arguments, and key concepts are pointed out.
Critical analysis of the paper position and suggestions of future directions. *(Weight 20%)*	The author does not offer a constructive critique of the used literature and perspectives. New contributions or new directions for research and practice are not suggested.	The author offers some constructive critique of the used literature and perspectives. Yet limited new contributions or new directions for research and practice are offered.	The author offers a constructive critique on the collection of articles and perspectives, states a position, and suggests new contributions or new directions for research and practice.
Quality of Writing • Clarity of sentences and paragraphs	The paper is poorly written, and contains many spelling and/or grammar errors. It is badly organized, lacks	The paper is mostly well written, without spelling or grammar errors. It is organized but the arguments are	The paper is well written from start to finish, without spelling or grammar errors. It is well

• No errors and spelling, grammar and use of English • Organization and coherence of ideas *(Weight 20%)*	clarity and/or does not present ideas in a coherent way.	not always clear and the ideas are not transparent to the reader.	organized, clear and presents ideas in a coherent way. The arguments are lucid and transparent to the reader.
References and use of references • Scholarly level of references • How effective the references are used in the paper • Soundness of references • APA style in reference list and for citations *(Weight 10%)*	Most of the references used are not important, and are not of scholarly quality. The resources are not used effectively. The references are not correctly cited and/or listed in the reference list according to APA style.	The paper references few references from the resource folders or course bibliography. Only few of the references are important, and not all of them are of scholarly quality. Most of the references are effectively used, correctly cited and listed in the reference list according to APA style.	The paper references articles from the resource folders, course bibliography and other sources, such as the ERIC or Academic Search Premier library databases. All the references are relevant and important, and are of scholarly quality. All the references are effectively used, correctly cited and correctly listed in the reference list according to APA style.
Overriding criterion: Originality and authenticity. If the paper is identified as not being original, and/or not done by the student, the instructor has the right to grade the paper as an F.			

References and Selected Online Resources for Mathematics and Science Teaching and Learning:

1. Critical Learning Instructional Path Supports (interactive activities in K-12 Math developed in Ontario: http://oame.on.ca/CLIPS/)
2. Gapminder: For a fact-based world view – unveiling the beauty of statistics (with Professor Hans Rosling) www.gapminder.org
3. Khan academy: http://www.khanacademy.org/
4. Inverted classroom: http://en.wordpress.com/tag/inverted-classroom-teaching/; http://www.slideshare.net/rtalbert/inverting-the-classroom-improving-student-learning?from=category_featured_email
5. SMART Exchange: http://exchange.smarttech.com/index.html#tab=0
6. MERLOT – Multimedia Educational Resource for Learning and Online Teaching: http://www.merlot.org/merlot/index.htm
7. ComPADRE: Resources for physics and astronomy education www.compadre.org
8. The biology corner: http://www.biologycorner.com/ - resource site for biology and science teachers.
9. Resources for biology teaching: http://www.ascb.org/ivl/design/education.html
10. Resources for mathematics education: National Council of Teachers of Mathematics http://www.nctm.org/
11. National Science Teachers Association: www.nsta.org

Additional references cited in this outline:

1. Koehler, M.J. and P. Mishra, *What is technological pedagogical content knowledge?* Contemporary Issues in Technology and Teacher Education, 2009. **9**(1): p. 60-70.
2. Jimoyiannis, A., *Designing and Implementing an Integrated Technological Pedagogical Science Knowledge Framework for Science Teachers Professional Development.* Computers & Education, 2010. **55**(3): p. 1259-1269.
3. Lasry, N., E. Mazur, and J. Watkins, *Peer Instruction: From Harvard to the two-year college*. American Journal of Physics, 2008. **76**(11): p. 1066-1069.
4. Bates, S. and R. Calloway, *PeerWise: student-generated content for enhanced engagement and learning*, in *Western Conference on Science Education*. 2013: London, Ontario.
5. Bates, S.P., R.K. Galloway, and K.L. McBride, *Student-generated content: using PeerWise to enhance engagement and outcomes in introductory physics courses.* 200?: p. 4.
6. Denny, P. *PeerWise*. 2014 [cited 2014 April 10, 2014]; Available from: http://peerwise.cs.auckland.ac.nz/.
7. Lasry, N., *Clickers or flashcards: Is there really a difference?* The Physics Teacher, 2008. **46**(5): p. 242-244.
8. Yourstone, S.A., H.S. Kraye, and G. Albaum, *Classroom Questioning with Immediate Electronic Response: Do Clickers Improve Learning?* Decision Sciences Journal of Innovative Education, 2008. **6**(1): p. 75-88.

9. Hoffman, C. and S. Goodwin, *A clicker for your thoughts: Technology for active learning.* New Library World, 2006. **107**(1228/1229): p. 422-433.
10. Duncan, D., *Clickers in the Classroom*. 2005, San-Francisco, Boston, NY: Pearson Education. 72.
11. Beatty, I.D., et al., *Designing effective questions for classroom response systems teaching.* American Journal of Physics, 2006. **74**(1): p. 31-39.
12. Milner-Bolotin, M., J. Cha, and K. Hunter, *Investigating Science Questioning Practices of Elementary Pre-Service Teachers: Design of Elementary Science Questions Evaluation Rubric*, in *American Educational Research Association Annual Meeting*. 2012, American Educational Research Association: Vancouver, BC, Canada.
13. Keller, C., et al. *Research-based Practices for Effective Clicker Use*. in *2007 Physics Education Research Conference*. 2007. Greensboro, NC: American Institute of Physics.
14. Zhou, G. and I. Lyublinskaya, *The Use of Graphing Calculator Technologies for Learning and Teaching Science and Mathematics at Urban High Schools*, in *Society for Information Technology & Teacher Education International Conference 2008*, K. McFerrin, et al., Editors. 2008, AACE: Las Vegas, Nevada, USA. p. 4387-4391.
15. Cortés-Figueroa, J.E., D.A. Moore-Russo, and M.J. Schuman, *Using a CBL Unit, a Temperature Sensor, and a Graphing Calculator To Model the Kinetics of Consecutive First-Order Reactions as Safe In-Class Demonstrations.* Chemistry Education, 2006. **83**: p. 64.
16. National Center for Education Statistics, *Teachers' Tools for the 21st Century: A Report on Teachers' Use of Technology*. 2000.
17. Antimirova, T. and M. Milner-Bolotin, *Introduction to Video-Based Motion Analysis*, in *Canadian Association of Physicists Congress 2009*. 2009: Moncton, New Brunswick.
18. Thornton, R.K. and D.R. Sokoloff, *Real Time Physics: Active Learning Laboratory*. The Changing Role of Physics Departments in Modern Universities: Proceedings of Icupe, ed. E.F. Redish and J.S. Rigden. 1997, College Park, MD, USA: The American Institute of Physics. 1101-1117.
19. Moll, R. and M. Milner-Bolotin, *The effect of interactive lecture experiments on student academic achievement and attitudes towards physics.* Canadian Journal of Physics, 2009. **87**(8): p. 917-924.
20. Loverude, M.E., *A research-based interactive lecture demonstration on sinking and floating.* American Journal of Physics: Physics Education Research Section, 2009. **77**(10): p. 897-910.
21. Milner-Bolotin, M., A. Kotlicki, and G. Rieger, *Can students learn from lecture demonstrations: The role and place of interactive lecture experiments in large introductory science courses.* Journal of College Science Teaching, 2007. **36**(4): p. 45-49.
22. Straits, W.J. and R.R. Wilke, *Interactive Demonstrations: Examples from Biology Lectures.* Journal of College Science Teaching, 2006. **XXXV**(4): p. 58-59.
23. Sokoloff, D.R. and R.K. Thornton, *Interactive Lecture Demonstrations: Active learning in introductory physics*. Physics Suite. 2004: John Wiley and Sons, INC.
24. Committee on Conceptual Framework for the New K-12 Science Education Standards; National Research Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. 2012. p. 401.
25. Perkins, K., et al., *PhET: Interactive Simulations for Teaching and Learning Physics.* The Physics Teacher, 2006. **44**(January 2006): p. 18-23.
26. Wieman, C.E. and K.K. Perkins, *Commentary: A powerful tool for teaching science.* Nature Physics, 2006. **2**: p. 290 - 292.
27. Finkelstein, N.D., et al., *When learning about the real world is better done virtually: A study of substituting computer simulations for laboratory equipment.* Physical Review Special Topics - Physics Education Research, 2005. **1**(1): p. 010103.
28. Finkelstein, N.D., et al. *Can Computer Simulations Replace Real Equipment in Undergraduate Laboratories?* in *Physics Education Research Conference*. 2004. American Institute of Physics.
29. Gee, J.P., *Learning by Design: good video games as learning machines.* E–Learning, 2005. **2**(1): p. 5-16.