INCREASING FEMALE ENGAGEMENT IN HIGH SCHOOL PHYSICS BY SUPPORTING DIVERSIFIED LEARNERS THROUGH A CONSTRUCTIVIST e-LEARNING ENVIRONMENT (DIGITAL LEARNING MANAGEMENT SYSTEM – (DLMS))

Assignment #1 – FRAMING A STEM ISSUE

submitted by Cassy Weber

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Dr. Christopher Rozitis

INTRODUCTION

There is growing concern regarding lagging student enrolment in high-school physics in Canada. Specifically, the *2016 Report on the Pan-Canadian Assessment of Science, Reading, and Mathematics* states that the majority of students are not choosing to take physics in high-school; and enrolment in senior-level, high-school physics has significantly lagged in comparison to chemistry and biology (Council of Ministers of Education, Canada (CMEC), 2016). In 2010, the number of diploma exams completed in physics was only 21% of the total diploma exams written in the major sciences (NSERC, 2010). Furthermore, the enrolment of females in senior-level physics classes has hovered around 38% between 2005 and 2010 (NSERC, 2010).

Since many engineering faculties require high school physics completion in order to meet enrolment criteria, the corresponding enrolment across Canada is also consistently low. Specifically, according to Engineers Canada (2012), in 2010, the national average undergraduate female enrolment in engineering was 17.7%, with a provincial breakdown as follows: Alberta 22%, Newfoundland and Labrador 20.9%, Saskatchewan 19%, Nova Scotia 18.7%, Ontario 17.7%, British Columbia 16.5%, Quebec 16.3%, Manitoba 16%, and New Brunswick 15.9%. The remaining provinces and territories were not reported.

Through an annotated bibliography, this essay aims to identify literature necessary to conceptually analyse theoretical frameworks which can support current research efforts into increasing student engagement in high school physics. My intentions are two-fold: First, I am interested in examining my existing perspective(s) on the issue of low female enrolment in physics to determine if my knowledge and insights will evolve based on my prior research and scholarly framing. Second, insights gathered through this analysis will serve to inform further product development and roadmap iterations in my professional capacity as a STEM educational technologist, specifically relating to the development of a digital learning management system (DLMS).

LITERATURE SEARCH

The curation of related literature resulted from consulting UBC's ETEC 533 Library Online Course Reserves, UBC's general ezproxy library access for distance learners, as well as my own scholarly collection of literature.

My preliminary survey of annotated literature was guided by interview questions and responses with Dr. Meera Singh and prior research, with focus on literature regarding TPCK (Mishra and Koehler, 2006), Index of Learning Styles (ILS) (Felder and Silverman, 1988), ICT-TPCK (Angeli & Valanides, 2009), integration of technology into teaching practices, (Messina and Tabone, 2012), computer technology as a means to improve student learning (Schacter and Fagnano, 1999), and technology enabled classrooms as a means to close the gender gap (Mayer-Smith, Pedretti, and Woodrow, 2000).

The issues to be considered through bibliographic annotations include: student learning style implications on engagement, student attitudinal insights into subject matter, use of

ICT/technology as a classroom engagement tool, and student context, foundationally grounded within an ICT-TPCK framework. The literature review has allowed for deeper contemplation into how a DLMS might increase student engagement, and ultimately, enrolment, in high-school physics.

KEYWORDS AND INCLUSION CRITERIA:

Keywords: technology, pedagogy, frameworks, social cues, diversity, learning styles, teaching, digital learning, K-12 physics, high school, experiential, collaborative, team-based, TPCK, ICT-TPCK, gender, female enrolment.

Inclusion criteria initially focused on literature, specifically journals, from 2005 onwards, then expanded to 1995 onwards. In addition, my focus included Canada only, then Canada and the United States, then expanded to include European countries such as Italy and Cyprus. I compiled a summary list of literature of fifteen or more articles relevant to the issue, specifically seeking to add depth of knowledge for my greater examination based on my prior research in this area. Finally, for this bibliographic annotation I selected five of the fifteen articles and will reserve the remaining analysis of literature for future research.

SITUATED RESEARCH

My prior co-authored research regarding increasing female enrolment in high school physics is summarized in conference proceedings for the American Society of Engineering Education (ASEE, 2016, 2019), Conceiving, Innovating, Designing, and Operating (CDIO, 2016, 2017), Canadian Coalition of Women in Engineering, Science, Trades and Technology (CCWEST, 2018), and Canadian Engineering Education Association (CEEA, 2018). The research is funded by NSERC and the Government of Alberta, and has focused on numerous scholarly aspects over the last four years including: benchmarking attitudinal insights in high school students and correlating same to learning styles; developing adaptive technology-based learning resources delivered within a DLMS platform; and incorporating blended learning through project-based lesson plans in combination with digital learning resource delivery within the DLMS. Bibliographic annotation insights will further my scholarly pursuits regarding situating current research within the conceptual ICT-TPCK framework.

STUDENT LEARNING STYLES, PRIOR RESEARCH

Research problem:

Do students have diversified learning styles, and if so, how do we index learning styles?

Prior research by Singh, Sun, Weber (2016) indicates there are numerous learning style models including Dunn and Dunn (1978), Meyers-Briggs (1962), Kolb (1984), and Felder-Silverman Learning Style Model (FSLM) (1988), which have been reviewed in preliminary research. All models classify students according to defined scales based on the way learners receive and process information, (Singh, Sun, Weber, 2016). The FSLM incorporates elements of the Myers-Briggs and Kolb's models, and also focusses on aspects critical to sciences and engineering.

The FSLM consists of four dimensions, each with two contrasting learning styles: Processing (*Active*/*Reflective*); Perception (*Sensing*/*Intuitive*); Input (*Visual*/*Verbal*); and Understanding (*Sequential*/*Global*). Further details of the dimensions can be found in Felder-Silverman's *Learning and teaching styles in engineering education*, 1988. In order to determine a specific learning style, Felder and Soloman developed the ILS survey (2001).

STUDENT ATTITUDINAL INSIGHTS INTO PHYSICS

Using the ILS, Singh, Sun and Weber (2016) surveyed 186 high-school students to determine what correlations exist between student interest in physics, learning style, and gender. Each student completed a multi-part survey including: 1) report on gender 2) response to attitudinal questions towards physics, and 3) completion of the ILS survey. The attitudinal insights aspect prompted students to respond on a five-point Likert scale (strongly agree to strongly disagree) and included questions such as "physics is hard", "physics is interesting", and "physics leads to rewarding career choices". Results of the 186 respondents are represented below:

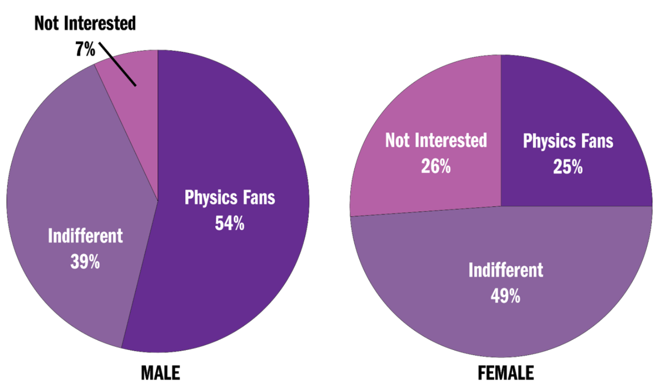

Figure 1. High-school students' attitudes towards physics, segmented by gender

Singh, Sun and Weber noted three distinct segments which emerged from the attitudinal survey, physics-fans, those indifferent towards physics and those not interested in physics, (2016). Notable findings include gender disparity as follows:

- Approximately 2:1 male to female ratio, pro-physics
- Approximately 4:1 female to male ratio, not interested in physics (physics-foes)
- Moderately higher female to male ratio, indifferent to physics

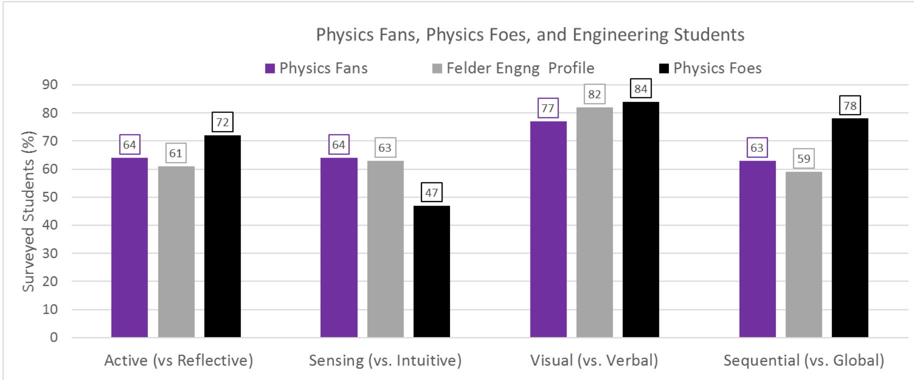

Figure 2. Comparison of Felder's baseline profile for post-secondary engineering students to high-school students

Additionally, Singh, Sun and Weber presented results of the physics-fans and physics-foes learning style profiles compared to baseline engineering students' data in Figure 2, noting the baseline was established by Felder and Spurlin (2005) through a compilation of ILS surveys completed by engineering students from ten North American universities. Notably, as reported by Singh, Sun, and Weber, "results of the physics-fans segment demonstrate a strong correlation in all four dimensions to the Felder profile for engineering students." And, unsurprisingly, significant differences were found to exist between physics-foes and engineering students, with physics-foes tending to be more active, intuitive, and sequential learners than physics-fans or engineering students.

CRITIQUE: INDEX OF STUDENT LEARNING STYLES

During my interview with mechanical engineering professor, Dr. Meera Singh (May 2019), when asked, "Do you support diversified learners?" She responded, "Understanding and supporting learning styles is of critical importance for student engagement." The above index of learning styles and results utilizes one model for assessment, and provides valuable insights into understanding student context.

EVALUATION

Future research will examine other models for application, such as Kolb's experiential learning theory (1984), which focuses on the learner's internal cognitive processes. The purpose of additional learning style modelling is to determine which benchmarking tool is most effective and informative for instructional design.

ANNOTATED BIBLIOGRAPHY

Research problem:

Does TPCK serve as an appropriate conceptual framework for integrating educational technology into student context/learning style (as well as pedagogy and content knowledge)?

Mishra, P. & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for integrating technology in teacher knowledge. *Teachers College Record, 108*(6), 1017- 1054.

Mishra and Koehler provide a conceptual framework, building on Shulman's seminal work, in linking pedagogy and content knowledge, incorporating the phenomenon of teachers integrating technology into their pedagogy. They argue that pedagogical uses of technology "require the development of a complex, situated form of knowledge that they call Technological Pedagogical Content Knowledge (TPCK)," (p. 1017). Employing a qualitative study to assess the development of TPCK, their summary insights are based on surveys to faculty/instructors and students, administered at the beginning of the semester and then at the end. Survey questions were developed using a Likert scale and short answer questions, and asked questions specific to the interrelatedness of TK, PK, CK.

The results of their study indicated that participants "moved from considering technology, pedagogy, and content as independent constructs toward a more transactional and codependent construction … and deeper understandings of the complex web of relationships between content, pedagogy, and technology and the contexts within which they function (emerged)," (p. 1044).

CRITIQUE: TPCK INSTRUCTIONAL DESIGN FRAMEWORK

Singh (2019) indicated that before we can achieve higher female enrolment in physics, we must first achieve higher engagement, thus implicating the need for a conceptual framework in order to consider all the contributing factors related to levels of engagement. Singh, Sun, Weber (2016) identified a student's learning style as a critical dimension influencing engagement.

According to Clinton and Hokanson (2012), "Creativity is not a special "faculty," nor a psychological property confined to a tiny elite. Rather, it is a feature of human intelligence in general. It is grounded in everyday capacities such as the association of ideas, reminding, perception, analogical thinking, searching a structured problem-space, and reflective self-criticism. It involves not only a cognitive dimension (the generation of new ideas) but also motivation and emotions, and is closely linked to cultural context and personality factors," (p. 113). Accordingly, then, an appropriate teaching framework is required, but so too, is an appropriate learning framework which supports an ‘unleashing of creativity’ in diverse students with distinctive learning styles and preconceived attitudes regarding physics.

According to Mishra and Koehler, “developing theory for educational technology is difficult because it requires a detailed understanding of complex relationships that are contextually bound,” (2006, p. 1018).

EVALUATION

While the TPCK model represents a framework for teachers to better understand the blending of content, pedagogy, and technology knowledge, and “allows teachers to make sense of the complex web of relationships that exist when teachers attempt to apply technology to the teaching of subject matter….” (p. 1044), it, however, does not directly contemplate student learning styles nor student context. Therefore, examination of other conceptual models which incorporate student knowledge and context is necessary.

Research problem:

Does ICT-TPCK serve as an appropriate conceptual framework for integrating educational technology into student context/learning style (as well as pedagogy and content knowledge)?

Angeli, C. & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: Advances in technological pedagogical content knowledge (TPCK), *Computers and Education.* 52, 154-168.

Angeli and Valanides introduce ICT–TPCK and describe it as an evolution of TPCK (Mishra and Koehler, 2006), and specifically, the ways in which “knowledge about tools and their affordances, pedagogy, content, learners, and context are synthesized into an understanding of how particular topics that are difficult to be understood by learners or difficult to be represented by teachers can be transformed and taught more effectively with technology in ways that signify its added value,” (p. 154).

“Repeated measures within-subject effects were tested and the results indicated that ICT–TPCK competency significantly improved over the course of a semester,” (p. 164). The test cohort consisted of three classes over three semesters totalling 215 pre-service teachers, with statistically significant findings regarding improvements in student performance. The researchers emphasized the “importance of examining the learner in interaction with others, and while this analysis was not the focus of the present investigation, they recommend it be performed in future studies regarding ICT-TPCK development,” (p. 166).

CRITIQUE: ICT-TPCK INSTRUCTIONAL DESIGN FRAMEWORK

ICT–TPCK conceptualizes two additional elements -- knowledge of students and knowledge of the context within which learning takes place, (p. 154). The evolved TPCK framework includes ‘learners’, which contemplates “their characteristics and preconceptions that they bring to a learning situation” and ‘context’, which ranges from… educational values and goals, and their philosophical underpinnings in conjunction with teachers’ epistemic beliefs about teaching and learning,” (p. 158). According to Valanides & Angeli, “ICT–TPCK can be defined as the ways knowledge about tools and their pedagogical affordances, pedagogy, content, learners, and context are synthesized into an understanding of how particular topics that are difficult to be understood by learners, or difficult to be represented by teachers, can be transformed and taught more effectively, in ways that signify the added value of technology. At the heart of this conceptualization is the view that technology is not a delivery vehicle that simply delivers information, but a cognitive partner that amplifies or augments student learning,” (p. 159). ICT-TPCK presents a compelling theoretical framework to conduct research regarding the efficacy of physics content within a DLMS.

Singh (2019) indicated that a critical factor in a student’s orientation and preconceptions regarding physics is their context. As example, in response to an interview question regarding gender gaps, she responded, “…possible reasons may include societal conventions which influence children’s interest, parental influence and/or absence of other possible mentors…”. In addition, Schnep’s *A Private Universe* (1988) demonstrates the common misconceptions held by students about scientific phenomena, which can be linked to student knowledge and context. The call-to-action in the video is clear: “Teachers must make (students) aware and enable them to learn, and free them from their ‘Private Universe’ of misconception.”

EVALUATION

ICT-TPCK provides a realistic conceptual framework to foundationally ground my current research. However, possible gaps in the ICT-TPCK framework include limitations on research regarding collaborative-constructivist based student progress. Specifically, ICT-TPCK student assessment was based on independent learning only. Therefore, specifically relating to student learning styles, positive ICT-TPCK outcomes regarding student performance cannot be concluded to be relevant to all students, particularly those who perform best in collaboration based, team problem solving.

Research problem:

How can teachers most effectively integrate technology into instructional practices within a conceptual ICT-TPCK framework?

Messina, L., Tabone, S. (2012). Integrating technology into instructional practices focusing on teacher knowledge. *Procedia - Social and Behavioral Sciences*, 46, 1015-1027.

Messina and Tabone address the issue of teacher training in technology and professional development, within Mishra and Koehler's (2006) TPCK theoretical model and Harris and Hofer's (2009) LAT-Learning Activity Types. The research explores the level of TPCK development "in a group of in-service teachers in order to find suitable ways to guide them in the integration of technology into their educational practices," (p. 1023), and focuses on the following: 1) survey of 110 teachers regarding their understanding of content knowledge and technology, and inter-relatedness and, 2) survey of 22 teachers regarding their understanding of related instructional design.

CRITIQUE: EFFECTIVE INTEGRATION OF TECHNOLOGY INTO INSTRUCTIONAL PRACTICES

While Messina and Tabone's research outcomes indicate that teachers' technological knowledge was weak and, their ability to relate insights into instructional design, pedagogical approach and planning, was also weak, they provided recommendations to invest in teacher training and competency building (p. 11). Of interest is the study's recommendation of best implementation protocol for TPCK in the following general planning sequence:

1. "Identify student learning goals
2. Consider the classroom context and student learning styles and preferences
3. Select and sequence appropriate learning activity types to combine and form the learning experience
4. Select formative and summative assessment strategies
5. Select tools and resources that will help best students benefit from the learning experience," (p. 9).

In alignment to Messina and Tabone's insights, Singh also indicated during the interview that she incorporates various technologies into learning, including data projection, iPad, computer simulations, experiential learning, clickers and videos/animations for demonstrations based on classroom context and student learning style. She emphasized the importance of diversified instruction as a means to support diversified learning. Specifically, her pedagogical approach to teaching in technology-enabled learning environments is designed to support numerous learning styles.

EVALUATION

Not all teachers/lecturers are knowledgeable in instructional design practices and planning. Therefore, an identified area for future research is to establish a benchmark assessment for teachers regarding abilities in instructional design theory and practice.

Research problem:

Can technology positively address gender-related gaps in levels of student engagement in physics classrooms?

Mayer-Smith, Jolie, Pedretti, Erminia, Woodrow, Janice. (2000). Closing of the gender gap in technology enriched science education: a case study. *Computers & Education*. 35 (1), 51-63.

Mayer-Smith, Pedretti, and Woodrow (2000) explore “a popular assertion, namely that success in technology enriched science classrooms is gender dependent,” (p.51). They investigated how students responded to a comprehensive integration of technology with learning of secondary science and physics. “Specifically, they asked: (1) Do female students view, participate, and achieve differently than male students in technology enhanced science classrooms? and, (2) If not, why not?” (p. 51).

The researchers collected empirical evidence over seven years, “which included classroom observations, student interviews and questionnaires, classroom achievement records, and journal entries” (p. 51). Their findings indicate that female students are successful at learning in technology enabled science environments and note, “this relationship among sound pedagogy, environment, and meaningful learning is not a novel concept, and has been regarded as critical by other researchers exploring the impact of computers in education,” (p. 59).

CRITIQUE: IS THERE A GENDER GAP IN TECHNOLOGY ENRICHED CLASSROOMS

Singh (2019) indicated during the interview that gender gaps may be fueled by stereotypes and misconceptions regarding a ‘typical’ physics student profile, referencing Sheldon from Big Bang Theory. The emphasis here is to dispel stereotypes and misconceptions, and to establish with students that technology as an enabler in a classroom is accessible to both males and females. In support of Singh’s assertion, from ETEC 533 week 3’s case study analysis, Teacher A in Learning Environment 2 was similarly aligned in philosophical understandings of how technology and pedagogy can be combined to support female student learning, and stated that female students indicate a higher than average rate of participation when working within a collaborative and technology-enabled learning environment. He too asserted that identifying misconceptions or conceptual challenges was critical to advancing the learning and understanding of students.

EVALUATION

In future research, investigative attention to technology-enabled learning and gender within a socio-constructivist learning environment in comparison to independent learning is required to determine if pedagogical practice is the over-riding influencer in context of student learning style.

Research problem:

Can a DLMS support increased student engagement in high school physics classrooms?

Schachter, John, Fagnano, Cheryl. (1999). Does Computer Technology Improve Student Learning and Achievement? How, When, and under What Conditions? *Journal of Educational Computing Research*. 20 (4), 329-343.

Schachter and Fagano (1999) argue that "ease and efficiency should not be the leading criteria for advocating and implementing computer technology in schools. The authors assert that to produce more meaningful learning, computer technologies need to be designed according to sound learning theories and pedagogy," (329). The study outlines that different computer technologies "serve and augment different learning experiences," (p. 329) and that teachers should make informed judgments "about which technologies are best suited to enhance student learning and achievement," (p. 329).

Of significance is Schachter and Fagano's findings that, based on 546 student test participants, Computer Based Instruction (CBI) moderately improved student learning (p. 330). Specifically, student test performance ranged from the 56th to 72nd percentile, compared to the control group that performed at the 50th percentile. The authors underscore the importance of aligning technology design with sound learning theories and pedagogy, and that when this is done effectively, then student learning can improve. On the other hand, they caution that CBI can focus more on 'skill and drill' versus deep cognitive development (p. 332). They explore various underlying CBI pedagogies including Behaviorist, Socio-Culture-Learning Theory, Computer-Supported Collaborative Learning, Constructivist Theories, Tool for Project-Based Learning, Cognitive Science, and Intelligent Tutoring Systems. Their research insights conclude by acknowledging there are many different technologies and that each can be effective at improving student performance, but to note that there is not a one-size-fits-all approach to reforming American schools (p. 339).

CRITIQUE: Does 'one-size' technology fit all?

Singh (2019) indicated during the interview that she wished she could access more high-quality computer simulations, both instructional and interactive. She explained that observable simulations were ideal for in-lecture instruction, while interactive were ideal for out-of-class learning. She noted that either a general lack of supply or high costs of software packages make this option mostly inaccessible.

EVALUATION:

Schachter and Fagano outline critically important insights specific to aligning educational technology design with pedagogical theory, while also pointing out that there are many possible combinations that can result in increased student engagement and performance. Generally speaking, future research will focus on gathering test insights specific to numerous pedagogically supported computer-based-learning experiences. The critical insights gathered might inform best pedagogical practices in context of learning style support.

CONCLUSIONS

Educational research focused on achieving higher female engagement in high school physics should consider constructivist theories foundationally grounded in the ICT-TPCK framework which consider epistemological influences of teaching and learning, student learning styles, context of teaching and learning, pedagogical theories, content and assessment tools as a means for amplified learning. Specifically, ICT-TPCK provides a theoretical framework in which both instructional practices and learning styles can be deconstructed and analysed for efficacy, and in which student learning processes and engagement can be assessed through a constructivist lens within an e-learning or DLMS supported environment.

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