Using Technology for Conceptual Learning in Physics Teacher Education: Engaging Teacher-Candidates as Learners and Teachers

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Abstract

Teacher-candidates' educational philosophies are influenced by their prior academic experiences. Teacher Education Programs (TEP) provide multiple opportunities for them to reflect on these experiences and to envision the learning environments they will design for their digital-savvy students. This places great responsibility on TEP instructors to model effective use of technology-based active engagement pedagogies in methods courses. The goals of the study are to (a) design and implement a physics methods course that uses technology-based active engagement as its guiding pedagogy; (b) explore teacher-candidates' conceptions of active engagement pedagogies and their place in teacher-candidates' epistemological views at two time points: directly following completion of the course and following their subsequent ten-week school practicum. Teacher-candidates participated in interviews at both time points. Results show that teacher-candidates hold complex conceptions of technology-based active engagement pedagogies and conceive of active engagement as a way to explore Pedagogical Content Knowledge. Implications for teacher education will be discussed.

Keywords: Educational technology, physics teacher education, active engagement, student engagement, science education, conceptual understanding, clickers, TPCK

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Introduction

Technology plays an ever-increasing role in the 21st century. However, ubiquity of technology does not guarantee that teachers know how to use it to create meaningful learning environments (Jonassen & Land, 2012). Research suggests that for technology to be pedagogically effective it should support active learning (Freeman et al., 2007; Laws, 1997). In contrast to traditional lecture-based pedagogy, active engagement has been found critical in promoting deep conceptual learning in both K-12 and post-secondary mathematics and science education (Hake, 1998; Mazur, 1997a). Conceptual understanding is defined here as the process of acquiring fundamental mathematics and science principles, recognizing their interconnections and limitations, and being able to apply them to novel situations (Bransford, Brown, & Cocking, 2002). Conceptual understanding has also been shown to be critical in helping students move along the novice-expert continuum while acquiring subject content mastery (Bilalić, McLeod, & Gobet, 2008).

A number of researchers have explored pedagogical strategies that promote active student engagement (Kalman, Milner-Bolotin, & Antimirova, 2010; Lasry, Mazur, & Watkins, 2008; Mazur, 1997b, 1997c; Milner-Bolotin, Antimirova, Noack, & Petrov, 2011; Milner-Bolotin, Antimirova, & Petrov, 2010; Moll & Milner-Bolotin, 2009). One strategy employs conceptual multiple-choice questions that use common student misconceptions as distractors. Unlike traditional "plug-and-chug" questions, these probe students' conceptual understanding. Low-tech (flashcards) and high-tech (electronic response systems or clickers) versions of this pedagogy rely on the use of meaningful conceptual questions to engage students in discussions (Lasry, 2008).

In order to successfully implement technology-based active engagement pedagogy in their practice, teacher-candidates have to possess content mastery and be aware of how students learn this content. Teacher-candidates should also have multiple opportunities to experience effective conceptual questions as both students and teachers. Thus, the goals of this study are twofold:

1. To design and implement a physics methods course that uses technology-based active engagement as its guiding pedagogy.
2. To explore teacher-candidates' conceptions of active engagement pedagogies and their place in teacher-candidates' epistemological views at two time points: directly following completion of the course and following their subsequent ten-week school practicum.

Literature Review and Theoretical Framework

This study was guided by two theoretical perspectives: the social constructivist views of learning (Bransford et al., 2002) and the Technological Pedagogical Content Knowledge (TPCK) framework (Koehler & Mishra, 2009).

The constructivist views of learning and teaching emphasize understanding versus memorizing facts and procedures (Bransford et al., 2002). This is especially relevant to mathematics and science education, where the value is placed on students' ability to apply concepts rather than recall information. According to constructivist views of learning, this can only happen if students take ownership of their learning by becoming active learners (Enghag, 2004; Laws, 1997; Milner-Bolotin, 2001). Active learning, however, does not take place in a vacuum: it happens when students interact with peers, teachers, and high/low-tech subject-specific resources (Bonwell & Sutherland, 1996; Milner-Bolotin, 2004, 2007; Milner-Bolotin, Kotlicki, & Rieger, 2007). The social aspect of learning has taken prominence in recent years in the form of social constructivist views of learning (Vygotsky, 1978) that also take into account the context in which learning occurs (Lave & Wenger, 1991).

Figure 1 depicts the modified Technological Pedagogical Content Knowledge (TPCK) framework used in the study (Milner-Bolotin, Cha, Chachashvili-Bolotin, & Raisinghani, 2013; Milner-Bolotin, Fisher, & MacDonald, 2013b). It is an extension of the Pedagogical Content Knowledge (PCK) framework proposed by Shulman (1986) and expanded by Koehler and Mishra (2009). TPCK emphasizes that successful teaching requires teachers to not only be masters of content (Content Knowledge) and have deep knowledge of students' potential difficulties, relevant pedagogical strategies, and possible connections between the content and students' lives and other areas (Pedagogical Knowledge), but also to be aware of modern technologies that can potentially facilitate learning (Technological Knowledge)(Milner-Bolotin, Fisher, & MacDonald, 2013a). The advantage of the modified TPCK is its emphasis on the knowledge of subject-specific technology-enhanced pedagogies. Thus, the biggest – initial gear is the Content Knowledge of a teacher-candidate, while the Pedagogical Knowledge and the Technological Knowledge are driven by it. TPCK is especially relevant to teacher education, as teacher-candidates have to be able to employ modern technology-enhanced pedagogies to help their students learn the subject.

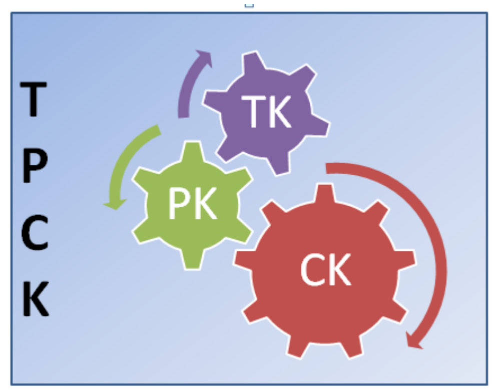

Figure 1. Modified Technological-Pedagogical-Content Knowledge Framework

Thus, the Content Knowledge of a teacher (or a teacher-candidate) drives the use of relevant pedagogies and relevant educational technologies.

Methods

This paper reports on the design and implementation of a technology-based active engagement pedagogy in a secondary physics methods course, as well as the corresponding qualitative research project. The study was designed to accomplish two research goals mentioned earlier:

1. To design and implement a physics methods course that uses technology-based active engagement as its guiding pedagogy.
2. To explore teacher-candidates' conceptions of active engagement pedagogies and their place in teacher-candidates' epistemological views at two time points: directly following completion of the course and following their subsequent ten-week school practicum.

From the design of the study and data analysis procedures, it is clear that school and course context, design and implementation were aimed at addressing the first goal of the study. At the same time, the data collection and analysis processes were aimed at addressing the second goal.

School Context

The study was conducted at a large research university in Western Canada. This university hosts a large Teacher Education Program, which certifies high school and elementary teachers, primarily in a one-year program. The program requires all teacher-candidates in the secondary cohort to participate in a 39 hours methods course in their teachable subject(s). Methods courses are designed to provide teacher-candidates with information that will be valuable when teaching in a subject-specific environment. This includes relevant pedagogies, technologies, activities, and unfamiliar content. The course described in this study is the methods course for prospective secondary physics teachers, and ran twice per week for an hour and a half, lasting thirteen weeks, during the Fall Semester 2012. The courses in the program are pass/fail, and to pass this methods course the instructor requires an approximate 80% grade.

Course Context

The course was led by one instructor and one graduate Teaching Assistant, and 13 teacher-candidates from various undergraduate backgrounds were enrolled (Table 1). Teacher-candidates received their undergraduate degrees from a variety of institutions: either from the same institution as their TEP, a different Canadian institution, or an international institution (denoted in Table 1 as Same, Different and International, respectively).

Table 1

Teacher-Candidates' Demographics

Undergraduate Program	Location of Undergraduate Degree	Teachable Subjects	Prior "clicker" experiences	Gender
Chemistry	Different	Chemistry, Physics, Junior Science	Yes	Female
Electrical Engineering	Same	Physics	Yes	Male
Engineering Physics	Same	Physics, Mathematics	Yes	Male
Physics	Different	Physics, Mathematics	Yes	Female
Physics	International	Physics	No	Female
Physics	Different	Physics, Junior Science	No	Female
Physics	Different	Physics, Mathematics	Yes	Male
Physics/Mechanical Engineering	Different	Physics, Junior Science	Yes	Male

This particular course aimed to introduce teacher-candidates to both the field of physics teaching and the field of physics education as a whole. The course objectives included teacher-candidates being able to: bring together pedagogical theory and classroom practice; become familiar with relevant educational technologies; develop skills for selecting appropriate methods, materials, and resources; and address the challenges associated with teaching physics to create pedagogically effective and supportive learning environments.

Course Assignments

The course had three major assignments. The first was designed to introduce teacher-candidates to the process of understanding how a student might think about a science topic. This involved interviewing a non-expert about a basic science topic, such as why we have seasons, and reporting on how the individual conceived of and explained the topic. Teacher-candidates were asked to probe their guest's thoughts to gain deeper understanding of where their conceptions originated. This assignment was worth 25% of their final mark. The second assignment involved a unit plan for one area of the curriculum, and four corresponding lessons. The grade for this assignment was divided into the draft (10%) and the final version (40%), allowing the instructor the opportunity to provide feedback before the teacher-candidates submitted a final version. The final assignment asked teacher-candidates to develop, critique, and adapt conceptual, multiple choice questions, or create their own. Teacher-candidates were given the option to create their own questions, or work from pre-existing questions from any available resource. One of these resources is the Mathematics and Science Teaching and Learning through Technology database of conceptual questions, designed by the research team (Milner-Bolotin, 2013). This assignment, worth 25% of the grade, was deemed of utmost importance by the research team, who place a high value on conceptual understanding, and recognize the difficulty of developing high quality conceptual questions.

Course Implementation

The course focused on active engagement, which was modeled by the instructor through clicker-enhanced pedagogy (Milner-Bolotin, 2004). The instructor and Teaching Assistant used conceptual multiple-choice questions and clicker-enhanced pedagogy to engage teacher-candidates in discussions surrounding relevant physics content, pedagogy, and stumbling blocks to learning, such as possible student misconceptions and conceptual difficulties. By engaging teacher-candidates in the discussion around the content and how to present it effectively to students, the goal was to empower teacher-candidates to incorporate active engagement in their own practice. Each class centred on conceptual questions, presented with clickers, where teacher-candidates were involved in discussions surrounding important concepts and how to integrate questioning into their practice. The following sequence illustrates one version of how this occurred: (a) the instructor poses a question and asks teacher-candidates to respond individually using clickers, (b) a histogram of their responses is revealed (Figures 2a-c), (c) teacher-candidates discuss their responses in small groups focusing on how secondary students might respond to the question, (d) teacher-candidates answer the same question individually a second time (Kalman et al., 2010). Other methods of implementing active-engagement pedagogies were also modeled and discussed.

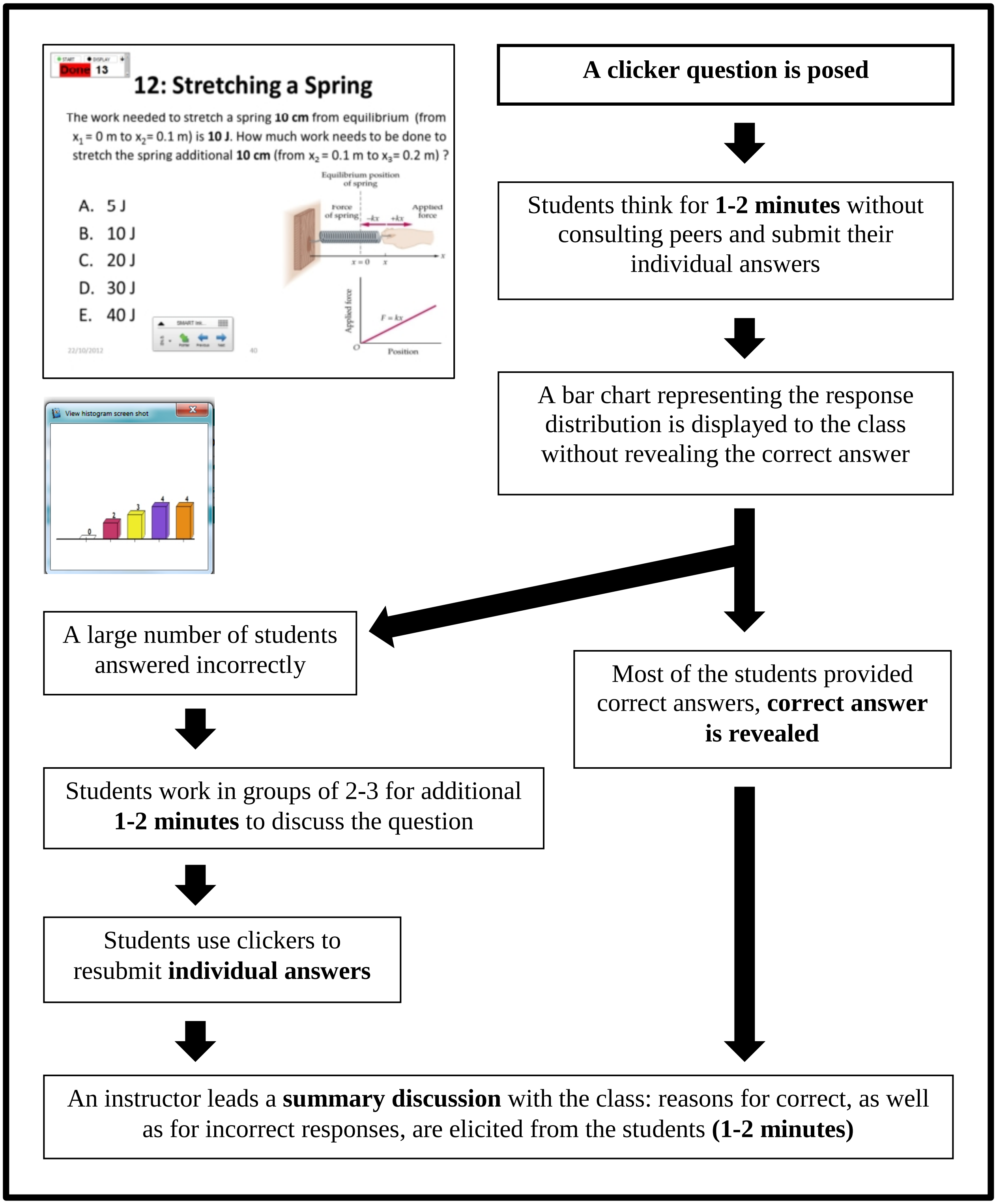

Figure 2a. Implementation of clicker-enhanced Peer Instruction pedagogy

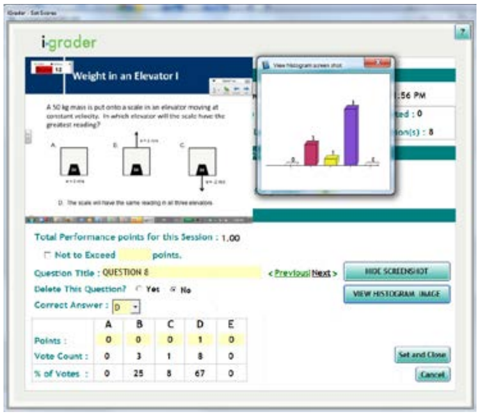

Figure 2b. A clicker response to a physics conceptual question

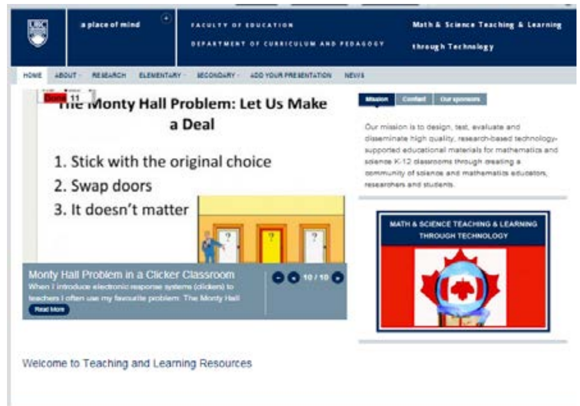

Figure 2c. Mathematics and Science Teaching and Learning through Technology web site: http://scienceres-edcp-educ.sites.olt.ubc.ca/

Data Collection

In the Winter Term of 2013, teacher-candidates were invited to participate in a series of interviews and focus groups. The timeline for the research project is described in Figure 3. The number of teacher-candidates participating in the different research components is as follows: eight in pre-practicum interviews, seven in post-practicum interviews, and six in the focus group. Four teacher-candidates contributed to all three sources of data collection, while the remaining participants only contributed to one. Each component of data collection served a specific research purpose (Table 2). For the purposes of this paper, only the interviews will be discussed, as the focus group was centered on a different

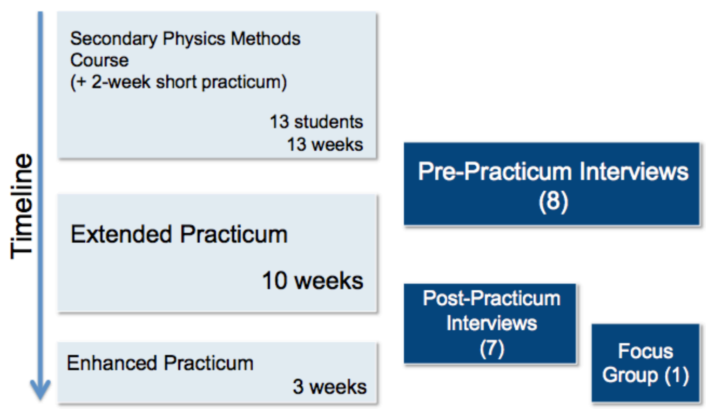

Figure 3: Research project timeline (Course-related components in light blue; research-related components in dark blue)

set of objectives and included a novel line of questions. A third-party researcher collected all data. Interviews and focus groups were transcribed verbatim and anonymized, after which the other researchers were granted access.

During the interviews, teacher-candidates were asked to reflect on their experiences as both learners and teachers. Particularly, how their experiences as learners translated into or informed their pedagogical choices as teachers.

At the first time-point (Table 2), directly following the course, the researchers were interested in examining teacher-candidates conceptions of clickers as a mechanism for pedagogy, mastery, TPCK, and the place of inquiry in secondary schools. At the second time-point, following their ten-week school practicum, we revisited clickers as a mechanism for pedagogy and TPCK, and probed teacher-candidates experiences designing and using conceptual research-based questions. A subsequent focus group was held, examining teacher-candidates' classroom experiences, their successes and challenges when implementing pedagogy, and the role of clickers in TPCK development. The results of the focus group are not reported here.

Table 2

Description of relevant independent and dependent study variables

Data Collection Method	Pre-practicum interviews	Post-practicum interviews	Focus group
Areas of Interest	• Clickers as mechanism for pedagogy • Mastery • TPCK • Inquiry in secondary schools	• Clickers as mechanism for pedagogy • TPCK • Designing and utilizing conceptual research-based questions	• Teacher-candidate classroom experience • Successes and challenges of pedagogy • Role of clickers in TPCK development

Data Analysis

Data analysis took place through two iterations. First, the research team explored teacher-candidates conceptions of active engagement through a free-structure analysis of the interviews. Second, all interviews were re-read through the lens of the TPCK framework to identify teacher-candidates expressions of PCK in the context of technology and explore changes in how teacher-candidates articulate ideas about PCK at the two time points.

Conceptions of active engagement. Qualitative content analysis (Bogdan & Bilken, 2007) was used to enable a contextualized interpretation and determination of the underlying themes of the interviews. Each researcher independently examined a subset of the transcripts and every transcript was examined by at least two researchers. Based on the questions asked in the interviews, a framework of potential themes was created, and this framework was expanded by individual researchers to include the major and minor themes present in each interview. After completing all initial analysis, the researchers met to discuss the overarching themes and their prevalence. From the major and minor themes within each interview, three overarching themes of the research were determined. These are discussed further in the results section of the paper.

Technological Pedagogical Content Knowledge. In order to examine the potency of TPCK in the teacher-candidates' epistemological views, the interviews were re-examined through the lens of the theoretical frameworks described above. Teacher-candidates were asked to describe their perceptions of the role of technology, or technology-based pedagogies in physics learning, as both learners and teachers. The research team read the interview transcripts in search of evidence, or lack of thereof, describing teacher-candidates' awareness, understanding, and incorporation of their TPCK in their practicum teaching.

Results and Discussion

The teacher-candidates in this study hail from a variety of backgrounds (Table 1). The most significant commonality between them was their enrolment in the same Teacher Education Program and the same Physics Methods course. Their views about teaching physics, therefore, were expected to vary greatly.

In spite of these major differences, three main themes were identified. Firstly, teacher-candidates view conceptual understanding as being integral to mathematics and science teaching. Secondly, they find student engagement essential for conceptual understanding. Finally, they view technology as an important mechanism to promote meaningful learning by actively engaging students.

Theme 1: Value of Conceptual Understanding

Teacher-candidates contemplated the purpose of teaching and learning extensively throughout the interviews. They also reflected on their role in these processes. The most common theme – both pre- and post-practicum – was the value of conceptual understanding over "plug-and-chug" approaches to learning. Throughout the interviews, teacher-candidates highlighted two facets of the value of conceptual understanding in teaching and learning – approach in theory and execution in the classroom.

Approach in theory. Teacher-candidates highlighted why having deep conceptual understanding is integral to physics teaching and learning. This included what mastery should, or could, look like in a secondary teaching setting, and how it directly impacts teaching. We refer to this as how they approached conceptual understanding in theory, separate from the application.

without being a master it's hard to find a good way to present the material efficiently and effectively... and also it's difficult to answer questions if you (pause) if you don't, well, if you don't know the answers. (Participant 9, Post-Interview 5)

Teacher-candidates saw conceptual understanding as essential for student success because problem solving in physics relies on the successful application of a few core concepts across unlimited novel contexts.

…physics is…not about applying formulas, and doing math. It is…about gaining an appreciation of the world around us. And, being able to use your understanding and extrapolate … explain what's happening around you. [It] Has nothing to do with math formulas. (Participant 15, Post-interview 1)

I think I've definitely got a better grasp on how it all fits together, I guess. 'Cause I sort of understood everything individually, and then when you teach it you kind of realize the connections more, which, I think, adds to the mastery level. (Participant 19, Post-Interview 3)

Execution in the classroom. Teacher-candidates outlined the successes and difficulties they encountered in incorporating conceptual questions into their practice, and how they were required to adapt their teaching method. In order to effectively incorporate conceptual questioning in to their classrooms, teacher-candidates had to consider classroom dynamics, the learning environment they wished to create, and how their students would respond.

Teacher-candidates described how using conceptual questions created a particular classroom dynamic, and were aware of the need to be flexible in order for students to respond.

I think the huge benefit to the clicker questions was having the class dynamic, where…I was more of a facilitator. (Participant 20, Post-Interview 2)

> *It sort of depends on the question and the class, um, and even the day. Like I, if I feel like they're engaged and they'll answer I tend not to give them the multiple choice and I'll just let them discuss and then give give an answer. But…particularly with the physics 11s I've found…you, I needed to give them the options… Um, particularly for the newer stuff too, so if I was just introducing it I tended to give options. Versus if it was the end of the class or a review-type question then I, it would be more like 'what do you think?' and have a discussion about it." (Participant 19, Post-Interview 3)*

Conceptual questions also posed a challenge when students' were unfamiliar with the purpose, or value, of having deep understanding of the topics they were learning, and preferred to focus on being right – and the resulting good grades.

> *My students ...will focus a lot more on...on figuring out what the...right answer is, rather than why it's the right answer. So if I do one of those things where I um you know display the results as they're coming in uh, you know if one answer gets a little bit ahead suddenly everyone will pick that answer and uh and it just goes off the charts and it's often wrong. So, that's one difference I noticed between…using clicker questions as a as a teacher and as a student is that the students will focus less on… the concepts and why the answer's right. Which is, not to say they don't focus on that at all, but it is sort of secondary. (Participant 9, Post-Interview 5)*

Teacher-candidates addressed this challenge, and altered their teaching strategies to help students see the value of conceptual understanding, and tried to move students away from their focus on marks.

Theme 2: Importance of Understanding Students for Effective Engagement

During the methods course, the instructor and Teaching Assistant consistently prompted teacher-candidates to think about how a student, unfamiliar with the content, might approach a new concept and where they might encounter difficulty. In this instance, the boundary between being teachers and being learners is fuzzy, as teacher-candidates often considered their experiences as learners when discussing how they would teach new concepts.

Teacher-candidates' were adamant that student engagement was essential for deep conceptual understanding, and if students were not engaged in the process during class it was unlikely students would understand the concepts at a deep level. In conjunction with this, teacher-candidates were aware of the importance of knowing their students, and the need to tailor their lessons and teaching style to the needs of their students.

> *I mean I didn't teach the physics for the full time, so I really I'd say only had like maybe a two-week period where I got to know the students well enough to be able to really get a feel for the for them and where they were. (Participant 2, Post-Interview 6)*

> *The idea of building it around the student I guess seems super intuitive now… It wasn't really clear to me to think about 'well, what kind of questions would the students have?' (Participant 19, Post-Interview 3)*

Teacher-candidates also recognized that students come from varying backgrounds and have different purposes for being in physics courses, and that these goals often differed from what their own had been as learners. The value of getting to know students proved invaluable for teacher-candidates in the development of their teaching philosophies and how they conducted a class.

So I think after going into the class it's just realizing...I guess how different the learners all are and how different they all are from me. (Participant 19, Post-Interview 3)

Be sensitive to the situation that...each of your students are in. ...realize that not everyone, you know... needs to get an A, not everyone wants to get an A. … not everyone needs to pass your course ...and not everyone has the same level of support from their parents, not everyone needs the same level of support from the teacher. Basically everyone is completely unique and comes from a completely different situation and you have to try and...figure out what that situation is and...create an individual relationship with each student that's tailored to that individual. (Participant 9, Interview 5)

By developing strong relationships with their students, teacher-candidates were also able to create environments where students were encouraged to take risks and be wrong in order to further their conceptual understanding.

Theme 3: The Role of Questioning for Learning

Within the Physics Methods course, teacher-candidates experienced the use of questioning as mechanism for deepening conceptual understanding. During their practicum, teacher-candidates saw the value of this pedagogy for themselves as teachers and as learners, and how it would help their students.

For me, as a first-time teacher, in order to see those misconceptions, it's super helpful to ask those conceptual questions. 'cause I don't know what they- I don't know what the misconceptions are yet. I'm still working on figuring out all the different thought processes a student could have (p. 8, Interview 3) [for developing mastery as a teacher]

It (good conceptual questions/Peer Instruction pedagogy) helps the students to see...what are the common mistakes that their classmates make, or that that they themselves make. … it

> *helps to you know reinforce that in most cases, depending on the question and the answers, that they're not the only person making the mistakes and that there's....some logic behind what they're thinking. … but it helps to show that ... if they're wrong that there is another way to think about it. (Participant 9, Post-Interview 5)*

Despite their belief that questioning is valuable for both the teacher and learner, the teacher-candidates met various challenges when integrating it into their classrooms. This included how questioning might benefit some students more than others.

> *I think it helps the one student that's really engaged in the conversation, it'll make them more of a master, because they'll understand the mathematical part, but as well as the more conceptual part. (Participant 20, Interview 2)*

Teacher-candidates also encountered push-back from students who had different views of success, and were interested in getting perfect grades to get into university. This was seen as a systematic issue that teacher-candidates could not change, but insisted on attempting to instill their value of conceptual understanding in their students.

> *… they're all like 'yes, great, so you, you've, you've prepared, prepared us for it. But if, because of this… it dragged our marks down, and we don't get into university, what's the point?' So they can see the value in it…kind of. B-but they're not sure it's worth it, at this stage. And…if I was in their shoe, I'd be, I'd be questioning the exact same thing. So, I, I absolutely understand it. And to me, this is a systematic problem. This is not a problem, … I can't blame the kids for thinking that. Um, because, it really is this whole system is doing this. They're used to being able to re-do things. They're used to having bonus marks. They're used to…here…my test is the exact same as my homework. They're used to the teacher telling them exactly what's on the test. So…when you combine all of those, of course your average is*

gonna be high. Of course everyone's average is going to be high. So that's a systematic problem…I'm gonna live with the consequences! If they…you know,…if I don't get a glowing review from them, that's a consequence I live with for being stubborn and holding it to that one (Participant 15, Post-Interview 1)

Concluding sentence lead us to consider teacher-candidates' PCK more closely.

Pedagogical Content Knowledge. Throughout the interviews, teacher-candidates discussed various aspects of Content Knowledge, Pedagogical Knowledge, and Pedagogical Content Knowledge (knowledge of physics in this study), and how these types of knowledge fit into their teaching philosophies. It was evident that teacher-candidates had thought about their Content Knowledge, and had a strong awareness of what mastery should look like for a secondary teacher.

I think you should be a master of…the content you will be teaching to the level that you will be teaching. In which case, which means, as a, as a graduate, um, from physics, am I going to be an expert in quantum mechanics and fluid dynamics? No. No, no I'm not, there's no way I can say I am. But ,… am I going to be proficient enough in, or should I be proficient enough, in …grade 12 physics? … Newtonian mechanics and the basics of electromagnetism? Yes, I think so. (Participant 2, Post-Interview 6)

Pedagogical awareness also played a key role in teacher-candidates' epistemologies. Teacher-candidates were prepared to describe their pedagogical choices to their students, demonstrating they believed it was important for a teacher to have strong reasons supporting their pedagogical decisions.

I mean I've always believed in giving a reason for doing what I do. Well, which is why I tell my students like 'look, if you have anything against what I do, if you, if you have any *questions about why I'm doing, you're like "this is stupid," you shouldn't need to do this, talk to me! Complain! Because, if you have, if it's legitimate, then I'll, then I, then I get to learn, saying well "this is a bad idea, I shouldn't be doing this" but if it's not illegitimate, and I'm doing it because I have a reason, then I will give you my reason, and I will tell you my reason. And , and you, you, whether or not you agree with my reason, whether you think it's reasonable, at least you'll know I'm not doing it just because I'm…evil...(Participant 2, Interview 6)*

Teacher-candidates were also aware of how their pedagogical decisions could support the development of important skills they valued, along with an appreciation for physics.

I would say my philosophy of teaching and education would be um one, encouraging passion and enthusiasm for the subject area. … and doing that by uh encouraging problem solving and critical thinking over rote memorization, um and plug and chug. Um, particularly encouraging the thought process um and discussion and...doing something wrong and figuring that out and then not penalizing them for it and allowing them that opportunity to struggle before you know before the success portion (Participant 19, Interview 3)

Finally, at the intersection of Content Knowledge and Pedagogical Knowledge, teacher-candidates were aware of how the two should interact, and how Pedagogical Content Knowledge impacts their students' learning. In particular, teacher-candidates considered where deficiencies existed in their knowledge, the difficulty of developing strong Pedagogical Content Knowledge, and how they could improve their Pedagogical Content Knowledge.

for Math 10 I definitely, there was a huge deficiency, and, just, I remember the stuff but I have no idea how to teach it to someone that…like, has never seen it before. So it took me a really long time to gauge the actual level of the students and then bring it down to their level. You *know, so that was definitely, I had the content mastered, but the delivery at their level was the deficiency. (Participant 20, Interview 2)*

I've realized now, since actually doing the practicum that the mastery not only means knowing the content but also recognizing where the students will struggle. (Pg. 1, Interview 3)

Conclusions and Significance of the Study

This study has demonstrated that modeling active engagement through technology in a Physics Methods course can facilitate the development of teacher-candidates' views on the role of active engagement in science teaching and their willingness to implement active engagement in their own teaching. While clicker-enhanced pedagogy was used as a mechanism to promote student active engagement, teacher-candidates were able to adapt it to low-tech or high-tech versions in their school practicum. Moreover, teacher-candidates were aware of the importance of their subject content knowledge for implementing student-centered pedagogies in their classrooms. The active engagement pedagogy modeled in the Physics Methods course was found to be effective in helping teacher-candidates improve their own Pedagogical Content Knowledge and become aware of the potential difficulties their students might experience while learning the subject.

Limitations

Although these findings provide strong support for modeling an active engagement pedagogy in teacher education, there are some limitations that should be noted. These are divided into two categories: the study design and the applicability of the results.

Teacher-candidates' views are complex and multi-faceted, having been formed over many years of educational experiences. This makes it difficult, in terms of the study design, to tease apart the impact of an individual course on those views. It is essential to consider the study in this light, as any changes in teacher-candidates' views that can be tied to the Physics Methods course represent a drastic change.

In addition to the inherent limitations of exploring such a complex topic, there are a number of logistic issues that could not be altered in the study design. For example, teacher-candidates expressed that the realities of their practicum settings – such as the educational community established by their School Advisors and the ten-week practicum timeframe – posed challenges to teacher-candidates interested in incorporating active learning pedagogies in their classrooms. Another potential challenge occurred in instances where teacher-candidates' pedagogical views were contrary to those of their School Advisors, preventing or constraining their implementation of alternative teaching methods. The amount of content the teacher-candidates were responsible for in their practicum classrooms also inhibited their ability to fully explore how conceptual questions could be implemented in a classroom setting.

Beyond the limitations of the study design, there is the limitation of applicability of identified themes in alternate educational settings. Teacher-candidates consistently demonstrated in both pre- and post-practicum interviews that they struggled to transfer their views about conceptual understanding and clicker-enhanced pedagogy outside of the physics classroom context. This was demonstrated by the inability of teacher-candidates with multiple teachable subjects to transfer their values and views across content areas. One possible reason for this might be that teacher-candidates were only exposed to conceptual questions in their Physics Methods course: teacher-candidates have not had sufficient time to integrate their constructs of teaching and learning into other subjects yet. However, we cannot be certain of this and further research is required to explore how to promote teacher-candidates' Pedagogical Content

Knowledge to help them implement concept-oriented mathematics and science learning environments in their future classrooms.

Future Directions

There is much room for continued research in this area. A quantitative analysis of the presence and growth of TPCK in teacher-candidates as they move through a Teacher Education Program would lead to better understanding of the impact of active engagement pedagogies on teacher-candidates' epistemologies and consequently on their teaching. In addition, a deeper examination of teacher-candidates' conceptions of active engagement and epistemological beliefs throughout the methods courses would be beneficial. This would allow researchers to better trace the impact of modelling pedagogies in methods courses during Teacher Education Programs and consequently made an impact on classroom teaching practicing.

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