PEDAGOGY IN LARGE LECTURE CALCULUS – TECHNOLOGY TO THE RESCUE

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Abstract

The transition from high school to college is extremely difficult for students, in many ways. In particular, attending classes in large lecture format (150 students or more) adds a considerable burden to students in their first year. This burden stems from the many issues that have diluted the pedagogical influence of teaching in large lectures, such as lack of interaction between students and their instructors, diminished class participation, diminished availability of contact hours with the instructors, lack of directional study, and disconnect in assessment of students expectations. Our work involves the integration of technological tools as effective means of instruction in large lecture settings that address some of these issues.

Specifically, we have developed Micro-videos, a Clicker Question bank, and electronic Flashcards to enhance the students' learning experiences. Micro-videos were developed to improve the student-instructor interaction outside of class. These are short videos (less than 10 minutes) presenting key calculus concepts and problems that are traditionally challenging for students. A Clicker Question bank was created on the topics covered in Calculus I to facilitate active participation and engagement in the classroom. A sustained pool of questions allowed the use of this technology more effectively and frequently thereby increasing the student in-class participation. Finally, the set of electronic Flashcards was created to provide students with a successful directional study approach. In this paper we report on the planning and implementation process of these technological tools, as well as preliminary findings from student perceptions on the use of these technologies.

Keywords: Innovation, technology, large lecture classes, Micro-videos, Flashcards, Clickers.

1 INTRODUCTION

Technology has become an integral part of classroom instruction. Over the last one and half decade, instructors all over the world have adopted various instructional tools such as PowerPoint, WebCT, and clickers, to keep up with the pace of the changing world of technology. A study conducted by Parker, Bianchi, and Cheah focused on faculty and students' perceptions of the impact of technology on student attendance, class discussion, and connections between students in large lectures [1]. They found that technology, when used as a means to organize course content, made the information delivery process more efficient in supporting large lectures.

Another area of technology used in higher education is multimedia technology. This has had a significant impact on the development of lesson plans and methods of communication with students. For example, at the Multimedia University in Malaysia, a multimedia project was embeded within a constructivist learning environment. A study found that students had positive attitudes towards the project with respect to their learning motivation and understanding [2].

The infusion of information and technology in mainstream teaching practices has led to new ways of thinking about learning. Lambert and McComb define learning for the next generations as the "Ability to retain, synthesize, and apply conceptually complex information in meaningful ways" [3]. This learning is particularly important for students who choose to take online courses. Matuga conducted a study that underlines the impact of technology on various aspects of an online course [4]. The online course was offered at Bowling Green State University. It was a self-regulated and goal-oriented course in science. The results indicated that students who were high achievers became more motivated and confident in their ability to learn when compared to their low and average achieving counterparts. Other evidence presented in this study suggests that there is a significant role that technology plays in supporting cognition and student learning in an online course at all learning levels.

As the option of online education and technology in the classroom becomes a viable option to the students, institutions are redirecting their infrastructure investments into technology to increase the instructional effectiveness [5]. Our institution has recently seen a transition in teaching first-year calculus. The class size of calculus courses has changed from class size of 35 students to large lecture class size of 150 students or more. Many instructors of these courses have turned to learn how to incorporate instructional technologies to help with the many issues that dilute the pedagogical influence of teaching in large lectures. These issues include, lack of interaction between students and their instructors, diminished class participation, diminished availability of contact hours with the instructors, lack of directional study, and disconnect in assessment of students expectations.

Our work involves the integration of technological tools as effective means of instruction in large lecture settings that address some of these issues. Specifically, we have developed Micro-videos, electronic Flashcards, and Clicker Question bank to enhance the students' learning experiences. In this article we provide details on how we developed these tools to aid the traditional teaching approaches in our calculus classes. We also present insights of students' perceptions about these tools. The article ends with concluding remarks that include future directions for research.

1.1 Micro-videos

In their studies about online learning environments, Peter Shea with Alexandra Pickett and their colleagues at SUNY have argued that student-instructor and student-student interaction are among the variables most strongly correlated with student satisfaction and self-reported learning [6]. As mentioned before, student-instructor interactions are affected in large lecture classes where contact hours are significantly reduced compared to regular-sized classes. To address this issue, we have developed what we call *Micro-videos*. Micro-videos can be used to support these interactions while promoting learning outside of the regular class time and place.

This tool consists of short videos that present key topics, calculations, or challenging problems in a concise fashion. The videos are posted online and can be viewed by students at a time most convenient for them. Hence, Micro-videos have the added benefit that students can watch them at their most convenient time and at their own pace. In Section 2.1 we provide further details of how we have incorporated Micro-videos in our calculus courses.

1.2 Electronic Flashcards

In the transition to college, most first-year calculus students are faced with the challenging task of changing their study habits, including developing new study strategies that differ greatly from the ones they used in school. The negotiations of first year students as they transition to college have received considerable attention among researchers [7-9]. Study habits are a vital factor in increasing academic integration as well as academic performance. However, many students are unaware of this important factor to college success.

In an effort to address this issue, we have developed a set of electronic Flashcards to assist students in the organization of their study materials, offering them a blue print of directional study that points to the key concepts in the course material. Flashcards were identified by Levine [10] as one of the academic strategies that provide learning support for students with certain disabilities. In recent years, researchers are encouraging the use of flashcards for *all* students [11,12]. In Section 2.2 we provide further details of how we have incorporated the use of flashcards in our calculus courses.

1.3 Clicker Questions Bank

For over a decade now instructors have been using 'Clicker' questions to increase classroom participation and, at the same time, obtain feedback on students' learning and understanding during lectures. With this technology, instructors can pose questions to the class which students answer using a transmitter, known as 'Clickers'. The class responses can be saved and then displayed in a variety of formats (histograms, pie charts, and so forth). When used appropriately, these results provide instructors an instantaneous assessment of the students' understandings and misunderstandings that help inform their pedagogical decisions; i.e., whether to move on to the next topic, or to further explain the current topic. The display of the aggregate responses can also be shown in class for students to monitor their own understanding as compared to the rest of the class and, when necessary, to open classroom discussions for students to clarify their ideas to each other [13]. Some researchers have reported how much students enjoy this technology and how it can create a positive and engaging learning environment in calculus classes [14-18]. These positive results have encouraged us to incorporate Clicker technology in our large lecture classes in an effort to increase student participation. In Section 2.3 we present further details of our work with this technological tool.

2 DEVELOPMENT OF TECHNOLOGICAL TOOLS

As it goes with technology there are certain resources that are needed to successfully implement these tools. For the use of Clickers a technology-ready (high-tech) classroom is necessary. Students need to buy clicker remotes to use in the classroom. Since Micro-videos and Flashcards are accessed electronically outside of the class, students need computer and Internet access. Instructors need a hand-held camera, a microphone, access to a well-lit room and a white board to make videos. They also need an editing software to create the Flashcards and Clicker Questions. In general, all these resources need a server to host them online. We discuss the development of these technological tools in detail in each of the following subsections.

2.1 Micro-videos

In this section we will discuss the nuances of what it takes to make a Micro-video. To increase the students' interest in using this tool, the videos should have an average length of 10 minutes. The preparations depend on the course for which the videos will be used. One must have a good understanding of the key concepts or problems that students struggle with the most; and understand why they struggle with them. This information will guide the careful selection of a problem(s) or example(s) to present in the video. Since the videos should be short (~10 min.), one is forced to choose the example(s) that best address the students' difficulty and help advance their level of understanding. For example, one of the videos we use focuses on the concept of Chain Rule, because we know that student find this particular topic difficult to grasp. In particular, they seem to get confused with the idea of finding the derivative of a composite function (function of a function).

Once the material to be presented in a video is chosen, it is not necessary to use state of the art technology to prepare these videos. It is necessary to have access to a quiet place with good lighting, a board, a digital camcorder, and a movie editor. For example, one could use a hand-held Cannon Vixia HF R100. This is a standard/high definition camera that records in MPEG4-AVC format. This has a USB terminal which helps directly transfer recorded files to a computer. Then the file needs to be reviewed for its audio and video quality. We have found iMovie software with Macintosh operating system to be extremely useful in terms of its video editing features. We have used iMovie to enhance the quality of the audio and to cut the parts of video that were unnecessary such as idle time or bloopers. The time taken to carry out the editing process depends on how well prepared one is at the time of videotaping. If one does a good job at the blackboard, then editing can take only 15 minutes.

In our experience it took a couple of tries to get a good product at first. Thus, we strongly recommend starting by videotaping a simple explanation in a 5-minute video. This will allow one to focus on the video quality rather than on the specific material. One should observe the same teaching practices used in the classroom. That is, not speaking to the board, speaking loudly, not covering the writing with the body, presenting the material in an organized way, and so on. This first attempt should be checked for (a) sound clarity (audible, clear, distance from camera, microphone), (b) lighting on the board and on presenter (avoid glares), and (c) writing readability (distance from camera). It is best to obtain feedback on this trial video from colleagues and students.

In our experience, once the initial challenge of choosing the appropriate content is taken care of, the making of the videos is a smooth process. Each 10-minute video can take anywhere from one hour to 3 hours to make. This includes the time to get the equipment set and everything ready to record (pre-processing), and the time to edit the video and make it ready for streaming (post-processing).

We have used a SMART board and have been very satisfied with the quality; however, this is not necessary for the success of this teaching practice. Fig.1 shows the screen shot of a Micro-video in which several examples of the application of the chain rule is explained.

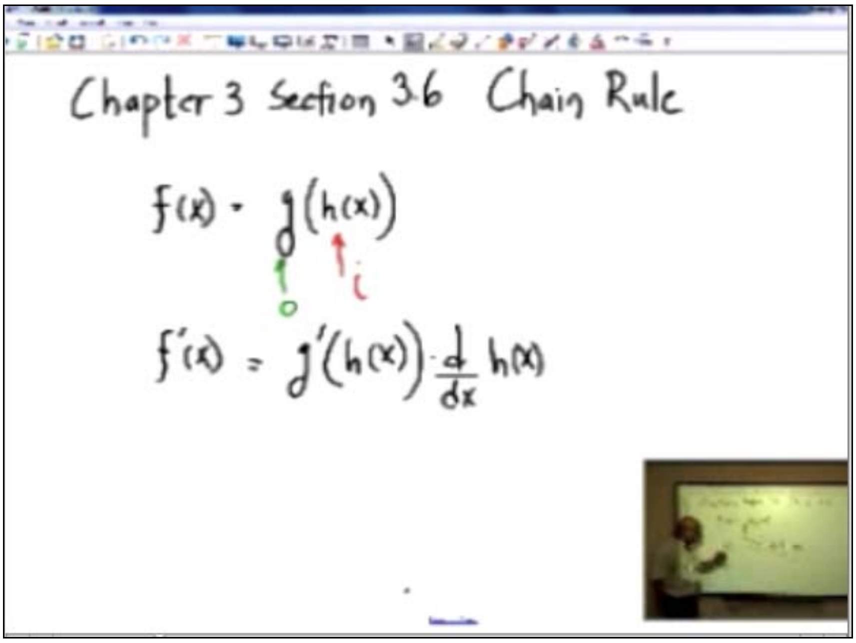


Fig.1 Screen shot of instructor Micro-video on the topic of Chain Rule

Opportunities for students to actively participate as they watch the video should be provided. This can be achieved, for example, by asking students to pause the video and work on a certain problem by themselves before they watch how it is solved on the video. As a final remark, it is important to recognize that the better-prepared one is to tape the video (just like one would be for a class), the smoother and faster the process will be.

2.2 Flashcards

Students make a transition from their high schools to the university setting in a short span of three months. As mentioned before, students have serious difficulty in organizing their study material. The primary purpose of developing these electronic Flashcards was to help students organize the material in their course in a systematic and concise manner. Students can use them during the class period to access previous concepts and outside of class in preparation for exams.

The Flashcards were prepared keeping in mind the general outline of topics for the course. Each chapter is divided into sections. Each section has various different subtopics, as well as important concepts that are necessary to understand subsequent sections or chapters. These subtopics were carefully chosen to anticipate their repeated used during the length of the course.

Electronic Flashcards were prepared using the text editing software `LaTeX'. This software allowed the use of technology to transform traditional flashcards, which have the question on the front and the answer on the back, to an electronic version. The electronic Flashcards are in the form of a PDF document. These can be downloaded by the students and printed on the paper. Fig. 2 shows an example of an electronic Flashcard with a unit circle. The left slide (front) indicates the question and right (back) indicates the corresponding answer.

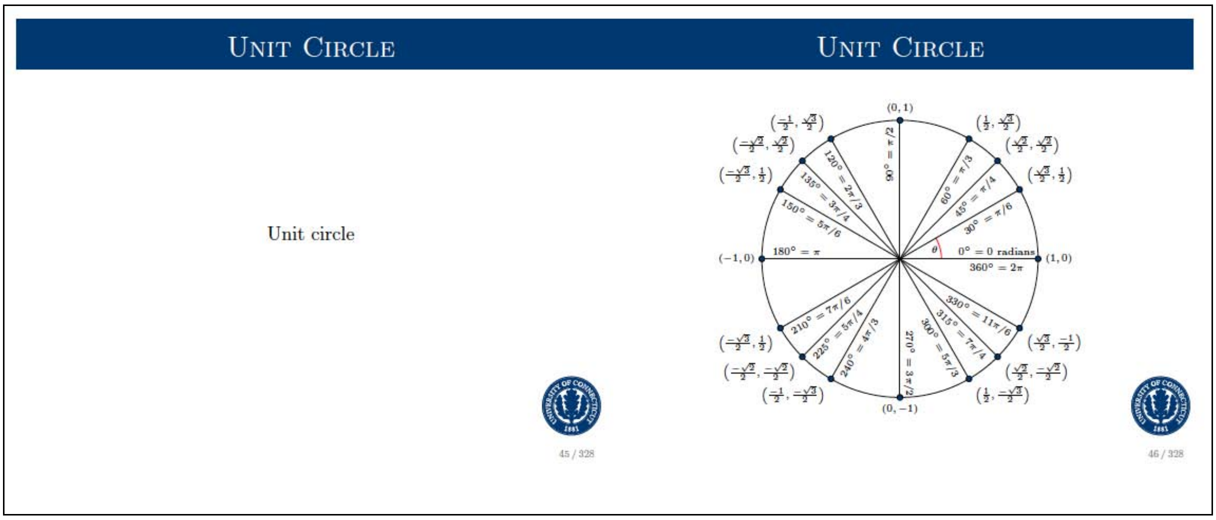


Fig. 2 Screen shot of an electronic Flashcard

Students don’t need to print these flashcards on paper since they are easily available as an electronic media. If the students should choose to print these, then it is recommended that they print six slides per page. They can then fold the paper in three equal parts and convert them into traditional paper flashcards.

2.3 Clicker Question Bank

As mentioned in Subsection 1.3, participation of students in large lecture classrooms has been one of the most challenging aspects of teaching in these settings. Clickers (Interactive response system) have been in use for over a decade to alleviate this problem. The success of this technology can be attributed to three factors: i) effective training in the use of technology prior to classroom implementation, ii) appropriate selection of questions to be used during the class period, and iii) clear communication with the students about the instructor’s purpose for using this technology in class.

The following procedure was used in the development of the Clicker Questions bank for our calculus class. Each section from each chapter was carefully scrutinized to create a set of four to five questions per section. These questions were prepared keeping in mind `what the instructor wants the student to understand while answering the questions’. These questions were prepared using `LaTeX’. A screen shot of a typical Clicker Question is shown in Fig 3. The left side shows what the students see first, that is, the question with the choices for answers. The right side shows the correct answer and its justification. The right side is shown to the students once the class has discussed the question.

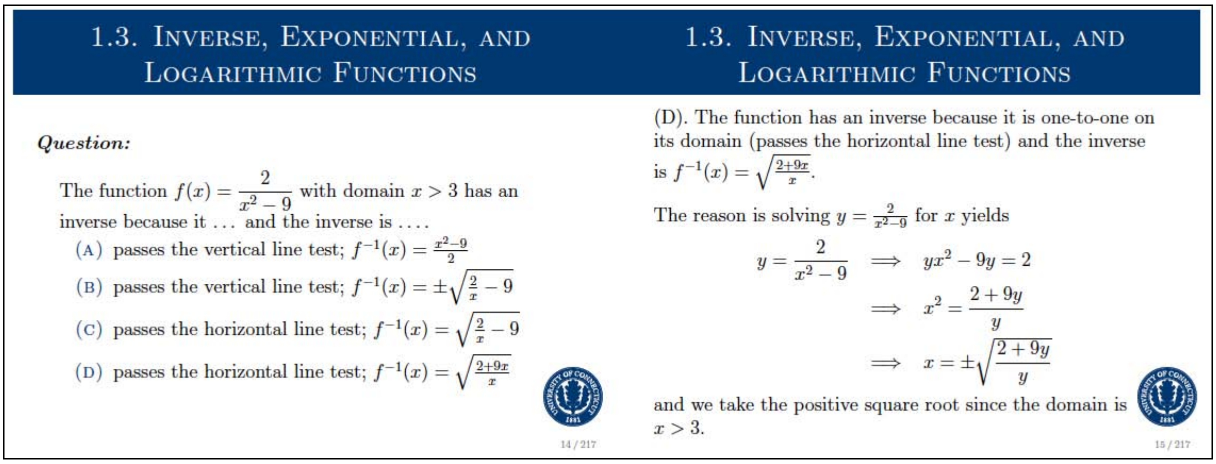


Fig. 3 Screen shot of Clicker Question on the topic of inverse functions

As mentioned earlier in this article, we created a sustained pool of questions to allowed the use of this technology more effectively and frequently thereby increasing the student in-class participation. This bank of questions is available to the instructors of different sections of the calculus course, which makes the use of this tool a homogeneous practice across all sections.

3 STUDENT PERCEPTIONS

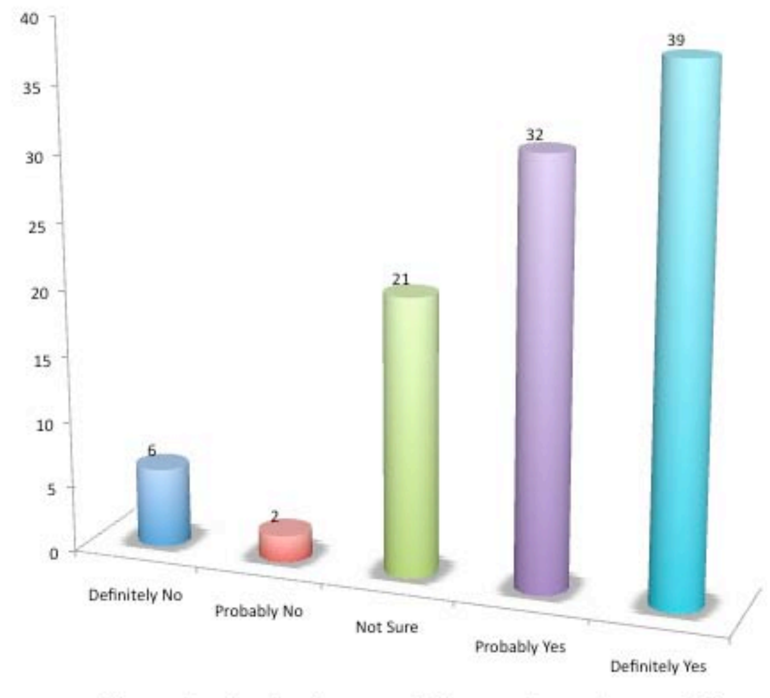
In this section we show some exploratory data on students' perceptions about choice to enroll in a class that provided each of the technological tools we have developed. The data presented here were collected in Fall 2010 from one section of a first-year calculus class. As a formative assessment, the instructor posed several questions in class and gathered the student responses using the 'Clicker' technology. The questions were aimed at understanding the general perceptions of the students about the calculus class. Three of those questions referred to each of the technological tools described in this article. The aggregate results on each of the three questions are presented here.

3.1 Micro-videos

One of the questions posed by the instructor to the students was the following:

Q: If you had a choice, would you choose to enroll in a mathematics class that provides Online Micro-videos?

A graph representing the students' responses to this question is shown in Fig. 4. Each of the possible five responses is given on the *x*-axis, these ranged from *Definitely No* to *Definitely Yes*. The *y*-axis, height of the cylinder, represents the total number of students who chose the corresponding response.



If you had a choice, would you chose to enroll in a mathematics class that provides online Micro-videos?

Fig. 4 Students' perceptions about Micro-videos

There were 100 unique responses to this question. As can be seen from the graph, the majority of these students, 71%, would choose a course that provides online Micro-videos. Very few students, 8%, responded that they would probably not or definitely not choose to enroll in such a course. While the rest of the students, 21%, answered that they were not sure about their choice.

Overall, these results suggest that students prefer classes that provide the Micro-videos. Since Micro-videos were used only outside of class, as a complement to the actual lecture, some students may not have been familiar with the Micro-videos. This may explain why some students were unsure of their choice. These responses presented here were anonymous; hence we lack further explanation from the very few students that chose *probably not* or *definitely not*. One may conjecture that these students prefer some other type of help outside of class, or prefer no help at all. It is important to note that peer tutoring, office hours, and other typical forms of outside help were available to all students.

3.2 Electronic Flashcards

Another question posed by the instructor to the students was the following:

Q: If you had a choice, would you choose to enroll in a mathematics class that provides Electronic Flashcards?

A graph representing the students' responses to this question is shown in Fig. 5. Each of the possible five responses is given on the *x*-axis, these ranged from *Definitely No* to *Definitely Yes*. The *y*-axis, height of the cylinder, represents the total number of students who chose the corresponding response.

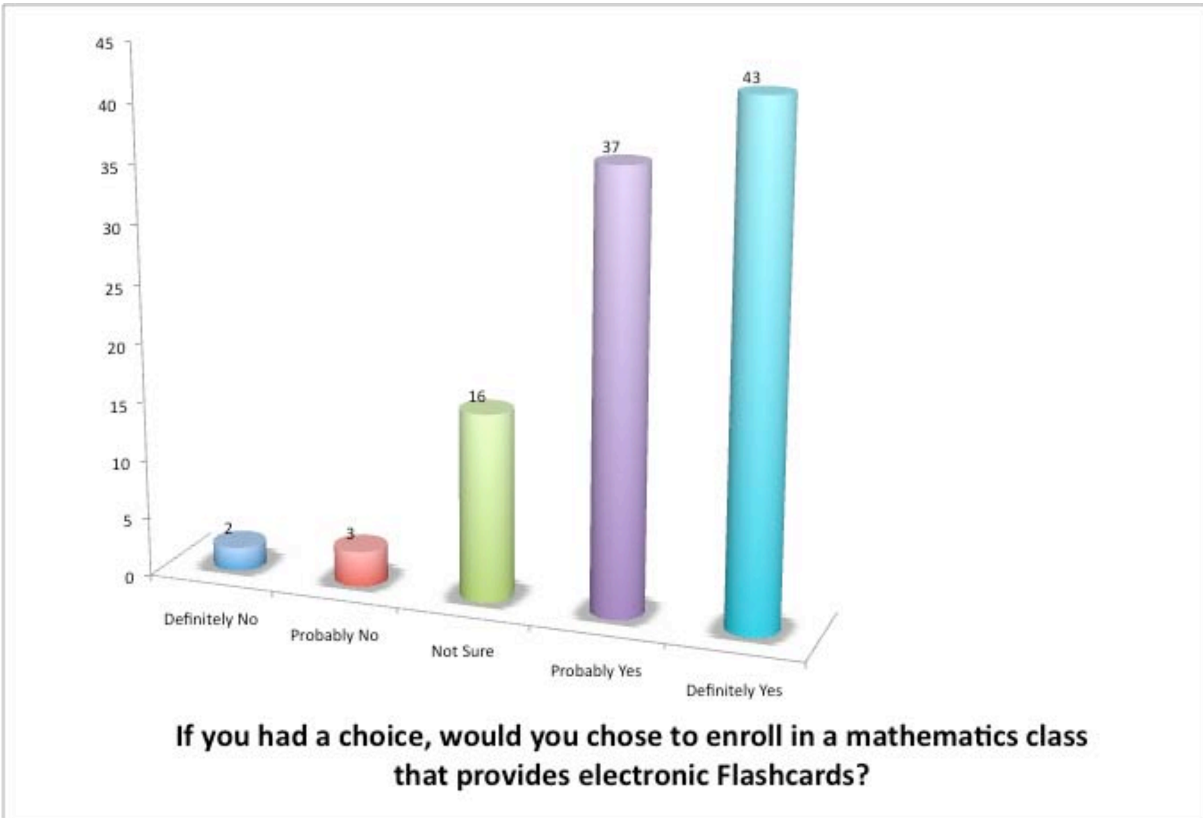


Fig. 5 Students' perceptions about Flashcards

There were 101 unique responses to this question. As can be seen from the graph, the majority of these students, approximately 79%, would choose a course that provides electronic Flashcards. Very few students, about 5%, responded that they would probably not or definitely not choose to enroll in such a course. While the rest of the students, about 16%, answered that they were not sure about their choice.

Overall, these results suggest that students overwhelmingly prefer classes that provide electronic Flashcards. As with Micro-videos, electronic Flashcards were used only outside of class, as a complement to the actual lecture, thus some students may not have been familiar with them. This may explain why some students were unsure of their choice. The responses presented here were anonymous; hence we lack further explanation from students, especially from the few who chose *probably not* or *definitely not* in this question. Given the non-intruding nature of electronic Flashcards, it is difficult to interpret these students' response.

3.3 Clicker Question Bank

Still another one of the questions posed by the instructor to the students was the following:

Q: If you had a choice, would you choose to enroll in a mathematics class that uses 'Clickers'?

A graph representing the students' responses to this question is shown in Fig. 6. Each of the possible five responses is given on the *x*-axis, these ranged from Definitely No to Definitely Yes. The *y*-axis, height of the cylinder, represents the total number of students who chose the corresponding response.

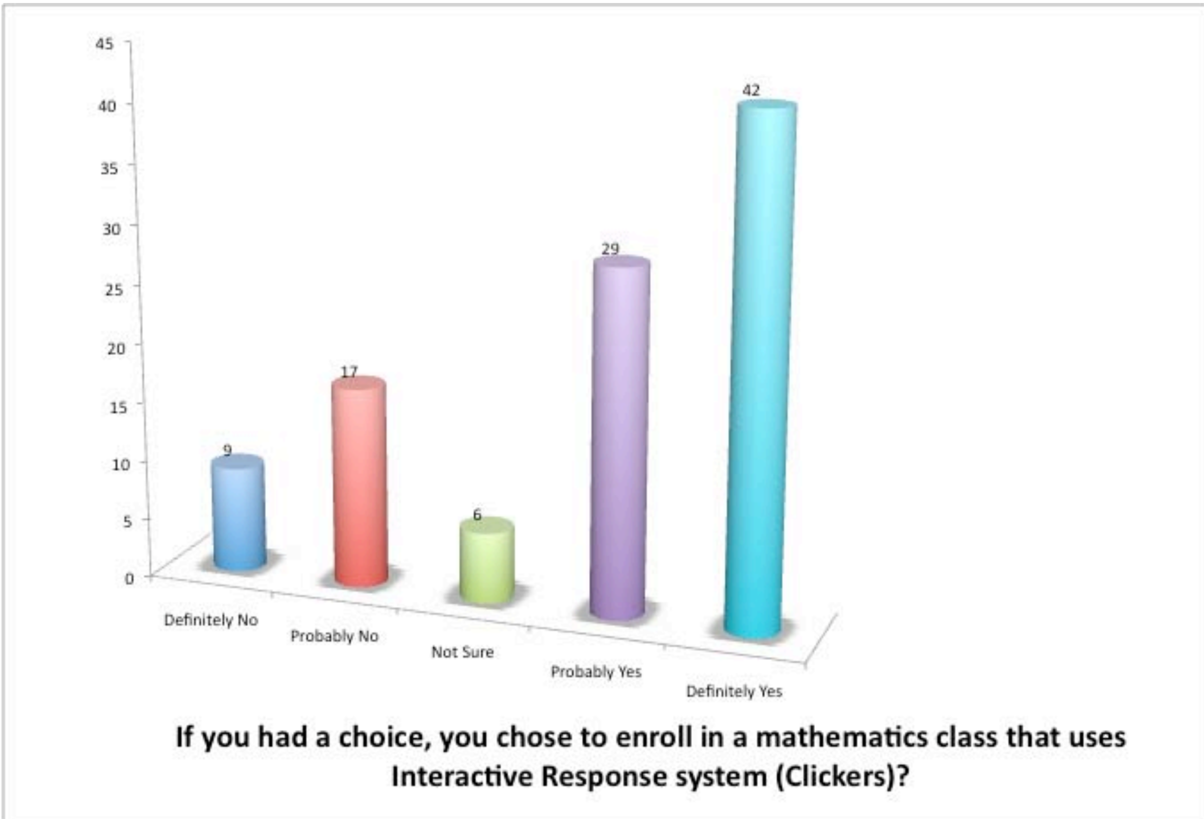


Fig. 6 Students' perceptions about Clickers

There were 103 unique responses to this question. As can be seen from the graph, the majority of these students, about 69%, would choose a course that uses Clicker technology. Some students, about 25%, responded that they would probably not or definitely not choose to enroll in such a course. While the rest of the students, about 6%, answered that they were not sure about their choice.

Overall, these results suggest that students prefer classes that use Clicker technology. Very few students were unsure about their choice. We have mentioned many of the advantages of this technology already (see Section 1.3); however, there are also some disadvantages related to Clickers, such as extra costs to students, that may explain the reluctance of some students to choose courses that use this technology. Since these responses were anonymous, we lack details to further interpret these students' responses.

4 CONCLUSIONS

With the growing tendency of offering courses in large lecture format, it is becoming increasingly important to understand the instructional tools that can be used to aid student learning in this setting. In this article, we have described the development and implementation of three technological tools that address some of the main issues of large lectures while helping students make a more comfortable and successful transition to college. Based on our experience, we are convinced that other educators would find that these tools are easily adaptable to their own classes to enhance learning.

Additionally, our exploratory findings indicate that the majority of the students prefer to enroll in classes that incorporate these tools. Further research is needed to confirm these results and extend our understanding of the use of these tools to positively affect student learning. Future research must focus on conducting rigorous and systematic studies about each of these technological tools. Based on our literature review, more studies are needed that examine how these tools affect student learning and student achievement, as well as studies that continue to explore students' and instructors' perceptions of the benefits of these tools from their perspectives. This article is the beginning of what we hope will become an important research endeavor for mathematics educators, as well as educators in other disciplines, on improving college teaching and learning.

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Impact of Mathematics Content Courses on Elementary Preservice Teachers' Confidence in Teaching Mathematics

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Abstract

There is a general consensus that mathematical content knowledge (M-CK) is crucial for enabling elementary school teachers to effectively teach mathematics. However, it has been suggested that M-CK is not sufficient for elementary school teachers – it must be accompanied by math pedagogical content knowledge (M-PCK). In order to better identify coursework that may promote M-CK and M-PCK, this study investigates confidence of M-CK and M-PCK of elementary preservice teachers (PSTs) who have participated in math content coursework designed for elementary teachers. Findings from preliminary work in a larger study suggest that PSTs who take one or more of these content courses, along with a mathematics methods course, have greater confidence related to M-CK and M-PCK than PSTs who take only traditional mathematics courses along with a mathematics methods course. The research is ongoing.

Current research suggests the importance of mathematical content knowledge to enable elementary school teachers to teach mathematics effectively (Ball, 2003; Ball, Lubienski, & Mewborn, 2001; Fennema & Franke, 1992; NCTM, 2003). However, there is not a consensus on how best to prepare elementary preservice teachers (PSTs) in order to achieve mathematical content knowledge (M-CK) that translates to effective mathematical pedagogical content knowledge (M-PCK) and, in turn, student learning (Kirtman, 2008). For example, Ball (2003) notes that "increasing the quantity of teachers' mathematics coursework will only improve the quality of mathematics teaching if teachers learn mathematics in ways that make a difference for the skill with which they are able to do their work. The goal is not to produce teachers who know more mathematics. The goal is to improve students' learning" (p. 1). In other words, more content area mathematics courses, while they may support increased M-CK, may not translate to M-PCK.

Investigating confidence of M-CK and M-PCK of PSTs related to specific course experiences during a teacher preparation program may allow researchers and teacher educators to better identify course experiences that may enhance M-CK and M-PCK of PSTs. This research investigated influences of mathematics coursework that has been *designed specifically with elementary PSTs in mind*—mathematics content courses taught in the Math Department, but with M-PCK as an emphasis. Confidence with respect to M-CK and M-PCK was investigated – comparing PSTs who participated in the specific math content courses with those who did not participate.

Perspectives

Research connected to self-efficacy (Bandura, 1986) and teacher efficacy (Henson, 2001; Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998) provides a framework for this study. Self-efficacy can be described as belief that one is capable of accomplishing certain tasks or goals (Bandura, 1986). Teacher efficacy relates to the teacher's belief in his/her capability to accomplish particular teaching-related tasks or goals (Tschannen-Moran et al., 1998). Teacher efficacy has been found to influence teachers' persistence and willingness to try new ideas; additionally, it has been linked to student outcomes such as achievement (Henson, 2001; Tschannen-Moran et al., 1998). Experts in instrument development, such as Gable and Wolf (1993), provide examples showing that self efficacy can be measured by rating confidence of specific beliefs about behaviors. This suggests that an instrument that measures confidence levels with respect to M-CK and M-PCK should provide indicators of self-efficacy with respect to these constructs. Indeed, NCTM (2003) noted, "Candidates' comfort with, and confidence in, their knowledge of mathematics affects both what they teach and how they teach it" (p. 4). Thus, assessing changes in PSTs' confidence toward M-CK and M-PCK may provide indicators of self-efficacy that may impact future mathematics teaching practices.

In order to measure confidence with respect to M-CK and M-PCK, we investigated instruments that have been used extensively and found to be trustworthy. The Fennema-Sherman Mathematics Attitude Scale (FSMAS) has been used for more than 20 years to investigate attitudes towards mathematics (Mulhern & Rae, 1998), providing a solid base from which to build an instrument to measure PSTs' confidence related to M-CK and M-PCK.

In addition to confidence, it is important to consider other indicators of M-CK and M-PCK. For example, Deborah Ball noted in remarks to the Secretary's Summit on Mathematics (2003) that teaching mathematics effectively in elementary schools requires that "teachers must know the same things that we would want any educated member of society to know, but *much more*" (p. 7). The "much more" (M-PCK) entails being able to ask and answer *why* about mathematical problems; fluency with and ability to strategically use representations; ability to inspect and make sense of and use students' mathematical methods; capacity to support mathematical language, and *much more*. Therefore, in addition to confidence items, we designed open-ended problems for the PSTs to complete that related to their own M-CK (solving and explaining mathematical problems) and their M-PCK (examining and commenting on non-routine student work). These provide additional data related to PSTs' M-CK and M-PCK that are aligned with ideas described by Ball (2003).

In Ball's remarks to the Secretary's Summit, she noted that few mathematics courses offer opportunities that would produce knowledge that is appropriate for elementary school teachers. Further, she urged that "ongoing research in this area is crucial" (p. 9). With these important issues in mind, we asked: Does elementary preservice teachers' confidence in M-CK and M-PCK change before and after completing the math methods course? If so, do the math content courses influence this change? In particular, in this article we explore the following research questions:

1. How does the change in confidence towards mathematical content knowledge (M-CK) before and after completion of a mathematics methods course compare between students who take math content courses designed for elementary school teachers and those who do not take these courses?
2. How does the change in confidence towards math pedagogical content knowledge (M-PCK) before and after completion of a mathematics methods course compare between students who take math content courses designed for elementary school teachers and those who do not take these courses?

An earlier paper (Truxaw, Cardetti & Bushey, 2010) reported on the collaborative process across the disciplines of mathematics and mathematics education that initiated these questions. This article builds from that work, focusing on the research questions themselves rather than the collaborative process.

Methods

Data for this paper are drawn from a larger research study that uses mixed methods (Creswell, 1998; Johnson, & Onwuegbuzie, 2004) to investigate influences of math content courses geared toward elementary PSTs. In order to examine confidence related to M-CK and M-PCK, a survey was administered that includes Likert items adapted from the *Fennema-Sherman Mathematics Attitude Scale* (Mulhern & Rae, 1998), along with open-ended content problems designed to uncover both M-CK and M-PCK. Additionally, the larger study includes interviews with a subset of the PSTs to provide supporting data related to the influence of the content courses.

Context

Participants are elementary PSTs enrolled in the teacher preparation program (TPP) at a large public research university in the northeastern United States. For the larger study, participants include elementary education PSTs in their junior and senior years in the TPP. These students are predominantly female (90-95%), white (80-90%), and typical ages range from 20 to 25 years old. For this paper, we focus on participants during the fall of their senior year, prior to and after completion of the required math methods course.

At our institution, all elementary education PSTs are required to take a mathematics methods course within the School of Education, along with at least three “quantitative” content courses (e.g., mathematic or statistics) outside the School of Education. The Department of Mathematics offers two content courses (recommended but not required by the TPP) for elementary PSTs. The courses have been created to develop an advanced perspective on and profound understanding of concepts, structures, and algorithms constituting the core of K-8 math curriculum. The topics of the course are chosen to support and extend the expectations set forth by the Mathematical Standards, K-8 (NCTM, 2000). The class meetings are structured to provide students with the experience of developing their own mathematical ideas. The instructor acts as a facilitator providing guidance to lead students toward understanding of concepts behind familiar concepts as well as new ones. Special attention is given to exploring and communicating the ideas and reasons behind the mathematical manipulations. Participants who completed either of these courses, along with the math methods course, are referred to here as the C-group (content). The participants who completed the math methods course, but did not complete either of the content courses recommended for elementary PSTs are referred to here as the NC-group (non-content).

Data Collection and Analysis

Data collection included pre- and post-surveys administered to the elementary PSTs in the math methods courses in fall 2009. Surveys included demographic items; Likert-type items to measure confidence in M-CK and M-PCK; and open-ended response items to gauge PSTs' facility to accurately complete and explain content problems, as well as to interpret and explain student work samples. Overall, 23 PSTs (11 C, 12 NC) completed the pre-survey, 32 PSTs completed the post-survey (16 C, 16 NC), and 19 PSTs (9 C, 10 NC) completed both pre- and post-surveys. Analysis focuses on the 19 participants who completed both pre- and post-surveys. It is important to note that the pre and post designations relate to the *methods course*, not the content course. Related to the research questions, we wondered if the C-group would begin the methods course with different levels of confidence in M-CK and/or M-PCK than the NC-group; *and* we wondered if the C-group would demonstrate different levels of *change in confidence* in M-CK and/or M-PCK than the NC-group (from pre to post methods course). In other words, we were interested in the impact of the specific content courses on confidence relative to the methods course.

For this paper we focus on the Likert-scale scores (1=Strongly Disagree; 5=Strongly Agree). The Likert-scale items were organized according to confidence in mathematical content (M-CK, items 1-4) and confidence in teaching mathematics (M-PCK, items, 5-8), as follows:

1. Generally, I feel secure about attempting mathematics.
2. I have a lot of self-confidence when it comes to math.
3. Mathematics is enjoyable and stimulating to me.
4. I would rather figure out a math problem myself than to have someone give me the solution.

5. Generally, I feel secure about teaching elementary school mathematics.
6. I have a lot of self-confidence when it comes to teaching elementary school mathematics.
7. Teaching elementary school mathematics is enjoyable and stimulating to me.
8. I would rather if my elementary school student could figure out a math problem rather than having me give them the solution.

Although items 4 and 8 relate to M-CK and M-PCK respectively, they deal less with overall confidence and more with a stance toward problem solving. Therefore, when items were aggregated for certain analyses, items 1-3 and items 5-7 were grouped and items 4 and 8 were considered independently.

A preliminary analysis focusing *only* on the change in mean differences of the Likert-scale scores was presented in Truxaw, Cardetti & Bushey (2010). In this study, we analyze the results of paired *t* tests (significant at the .05 level) using SPSS software (Green, Salkind, & Akey, 2000) comparing these mean differences (pre-score minus post-score – a negative difference indicating positive change). Due to the small sample size, we report a 95% confidence interval (CI) of the paired *t* test analysis rather than the *p*-values. If zero did not fall within the range of a 95% CI, it indicated 95% confidence that the difference between the pre- and post-survey means was not zero and, therefore, the mean difference was significant (Shavelson, 1996).

As the larger study progresses, results are being triangulated through analysis of the open-ended content problems and interviews. The open-ended content problems are being scored using rubrics that have been developed, refined, and tested for inter-rater reliability (90% or higher). The interview data is being coded and analyzed thematically (e.g., Creswell, 1998; Strauss & Corbin, 1990). This paper reports on findings from the Likert-items, along with some preliminary findings from the open-ended items.

Results and Discussion

In this section we present results of analysis used to answer the research questions (RQs) along with related explanations and discussion. We present descriptive statistics, mean differences, and the 95% CI for a mean difference for the corresponding Likert item scores, along with explanations and discussion of these results. Our analysis and discussion focus on the statistical significance of each individual item, as well as on the aggregated data for groups of items corresponding to different constructs.

RQ 1: Comparison of elementary PSTs' Confidence in Mathematical Content Knowledge

To answer the first RQ, data from pre- and post-scores of the Likert items related to M-CK (items 1-4) were analyzed. Table 1 summarizes the changes in pre- and post-scores for each of the M-CK-related items for the C- and NC-groups.

Table 1

Confidence Toward Math Content

	Pre		Post		*Mean Difference pre-post*	*95% CI Mean Difference*
	Mean	*SD*	*Mean*	*SD*		
Content Group, *n = 9*						
Item 1	4.44	.53	4.33	.50	.11	(-1.00, .20)
Item 2	4.44	.73	4.00	.50	**.44**	**(.04, .85)****
Item 3	4.33	1.00	4.22	.44	.11	(-.60, .824)
Item 4	4.22	.67	4.44	.53	-.22	(-.86, .42)
Non-Content Group, *n=10*						
Item 1	3.40	.97	3.80	.63	-.40	(-1.00, .20)
Item 2	3.10	.87	3.40	.84	-.30	(-.78, .18)
Item 3	3.20	.79	3.50	.71	-.30	(-.65, .05)
Item 4	4.00	.47	4.00	.47	.00	

**Significant at the 95% CI level

Before making pre and post comparisons, it should be noted that mean scores for *every item* related to M-CK, both pre and post, were higher for the C-group than for the NC-group. In terms of pre and post comparisons, for the C-group, only one item (item 2 - *I have a lot of self-confidence when it comes to math*) showed significant change at the 95% level from pre-to post-survey (*95% CI*, (.04, .85)). A large effect size of .72 was found for this item when comparing pre- and post-survey scores. Interestingly, the change was a *negative* one – that is, the C-group reported significantly *less confidence* for this item than prior to participating in the methods course. Although not significant, mean scores for items 1 and 3 decreased from pre to post; for item 4, mean scores increased from pre to post. For the NC-group, although no single item showed significant changes, the mean scores showed *increases* in reported confidence for three out of the four content-related items (items 1-3) and *no change* for item 4.

There were interesting, although not statistically significant, observations of the data related to item 4 (*I would rather figure out a math problem myself than to have someone give me the solution*). While the mean scores for the C-group on item 4 increased (pre, *M*=4.22; post, *M*=4.44), these were not significantly different at the 95% CI level. For the NC group there were no changes for this item in means or standard deviations (pre and post, *M*=4.00, *SD*=0.471). However, these results show that both groups reported consistently high expectations for allowing themselves to struggle when working through mathematical problems, with the C-group reporting slightly higher levels and slight increase from pre- to post. These results will be discussed further in comparison to a similar item (item 8) related to M-PCK.

Additionally, to further understand changes in pre- and post-scores for each group related to this RQ, three Likert items constituting a single construct, confidence toward M-CK, were identified (items 1-3). The aggregate scores' mean differences and CIs were analyzed for the two groups separately. The analysis yielded no significant change at the 95% level for the C-group

(Mean difference, .22; *95% CI*, (-.12, .56)). However, a significant (positive) change was noted for the NC-group (Mean difference, -.33; *95% CI*, (-.65, -.02)). A medium effect size of .48 was found for this construct when comparing pre- and post-survey scores. These results suggest that the NC-group of PSTs showed significant growth in confidence toward M-CK after completing the math methods course. One may conjecture that NC-group's lack of exposure to the M-CK courses may have impacted their need to focus on the mathematical content while in the methods course.

RQ 2: Comparison of elementary PSTs' Confidence in Mathematical Teaching

To address the second research question, data from the pre- and post-scores of the Likert items related to M-PCK (items 5-8) were analyzed. Table 2 summarizes the changes in pre- and post-scores for each of the M-PCK related items for the C- and NC-groups.

Table 2

Confidence Toward Teaching Math

	Pre		Post		*Mean Difference pre-post*	*95% CI Mean Difference*
	Mean	*SD*	*Mean*	*SD*		
Content Group, *n=9*						
Item 5	3.33	.50	3.78	.67	**-.45**	**(-.85, -.04)****
Item 6	3.22	.67	3.78	.67	**-.56**	**(-.96, -.15)****
Item 7	3.67	.87	4.00	.71	-.33	(-.72, .42)
Item 8	4.89	.33	4.89	.33	.00	
Non-Content Group, *n=10*						
Item 5	3.70	.48	3.20	.79	.50	(-.11, 1.11)
Item 6	3.10	.57	2.80	.79	.30	(-.46, 1.06)
Item 7	3.30	.48	3.10	.74	.20	(-.46, .86)
Item 8	4.50	.53	4.50	.71	.00	(-.48, .48)

**Significant at the 95% CI level

Before reporting results of the CI analysis, it is worth noting general trends related to confidence toward teaching mathematics. Although the results were less definitive than for M-CK, the mean scores related to M-PCK suggest greater confidence by the C-group than the NC-group. For example, prior to taking the math methods course, the C-group reported greater confidence than the NC-group on three of the four items (items 6, 7 & 8). After completing the math methods course, the C-group reported greater confidence than the NC-group *on every item* related to M-PCK.

For the C-group, the analyses of the CIs for mean differences showed significant increases at the 95% level from pre- to post-survey for items 5 (*95% CI*, -.85, -.04) and 6 (*95% CI*, (-.96, -.15)). Large effect sizes of 0.88 and 0.84, respectively, were found when comparing pre- and post-survey scores for these items. For item 7, the C-group showed an increase in mean scores, but the change was not significant at the 95% level; for item 8, there was no change in mean scores or standard deviations (pre and post, M=4.89, SD=0.333). For the NC-group, although there were decreased mean scores on three of the four items (items 5, 6 & 7), none of the changes were significant. For item 8, the NC-group showed no change from pre- to post-survey in the mean scores (pre, M=4.50, SD=.527; post, M=4.50, SD=.707). These results show that both groups reported consistently high expectations for allowing their students to struggle when working through mathematical problems, with the C-group reporting slightly higher levels.

Additionally, to further understand changes in pre- and post-survey scores for each group related to M-PCK, three Likert items constituting a single construct: confidence toward M-PCK were identified (items 5-7). The confidence intervals for aggregate means differences on pre- and post-scores for this construct were analyzed for the two groups separately. The analysis yielded a *positive* significant change at the 95% level for the C-group (*Mean difference*, -.44; *95% CI*, (-.76, -.13)). A moderately large effect size of .68 was found for this construct when comparing pre- and post-survey scores. However, no significant change was noted at the 95% level for the NC-group (*Mean difference*, .33; *95% CI*, (-.24, .91)). These results suggest that the C-group of PSTs showed significant growth in confidence toward M-PCK after completing the math methods course. One may conjecture that the C-group of PSTs' prior exposure to M-CK courses may have provided them content knowledge that allowed them to focus on the pedagogical content while in the methods courses, thus increasing their confidence with teaching mathematics while participating in the math methods course.

There were interesting observations of the data related to item 8 (*I would rather if my elementary school student could figure out a math problem rather than having me give them the solution*). This question was designed to parallel item 4 in the M-CK section (related to a similar stance toward their own problem-solving). As noted, neither group of PSTs reported changes related to item 8. Recall that for the NC-group there were no changes in mean scores for item 4 either – that is, the NC-group reported no change in stance toward problem-solving for themselves or for their students. For the C-group, there was a slight increase in expectations related to their own problem solving, but no increase in expectations toward preferences for their students' problem solving. It should be noted that both groups reported high expectations for both themselves and their students related to persistence with problem solving. Even so, it is interesting to observe that, for both C- and NC-groups, the mean scores for item 4 (expectations for self) were *lower* than the mean scores for item 8 (expectations for students) – suggesting that the PSTs may have different mathematical expectations for themselves than for their students.

Preliminary Findings from Open-Ended Content Items

Results from open-ended content items are being used to corroborate findings from the survey related to PSTs' M-CK and M-PCK. Analysis of these items is in progress. They are being scored using rubrics that have been developed, refined, and tested for inter-rater reliability (90% or higher). Preliminary results from analysis of a subset of the larger data set suggest that the C-group, as compared to the NC-group, of PSTs demonstrates stronger content knowledge for doing math, interpreting student work, attempting explanations, and providing reasonably accurate/appropriate explanations. This ongoing analysis will further support this research.

Limitations

One limitation of this study is its small sample size. However, the results demonstrate significant means difference at the 95% confidence level. This suggests that if hypothesis testing were performed that the results would likely reach statistical significance. We expect to confirm this statement as we continue to collect and analyze data over time. Another limitation may lie in the particular TPP where these data are collected. More research studies, both incorporating more participants and within other TPPs, could provide further evidence of the extent to which the findings reported here are representative of the experiences of other PSTs in other TPPs. Finally, this research investigates *confidence* rather than knowledge or observed teaching practices; while confidence provides a window into potential knowledge and practice, we recognize that there are limitations in using this approach. Future research investigating a link between confidence and performance will continue to grow the body of literature on preservice elementary preservice teachers' mathematics and pedagogical content knowledge.

Final Remarks

This study sought to uncover influences that mathematics content courses designed for elementary PSTs may have on the PSTs' confidence toward M-CK and M-PCK. The findings indicate that the C-group showed greater gains than the NC-group in confidence towards M-PCK after taking the required math methods course. Interestingly, students in the NC-group reported greater gains than the C-group in confidence towards M-CK. These results suggest that PSTs going into the methods courses with greater M-CK may potentially increase their confidence in M-PCK, and that this increase could be to a greater extent than those with less M-CK experience. The NC-group's gains in M-CK and relative lack of gain in M-PCK from pre- to post-methods course may suggest that their attention was focused more on the mathematics content than the teaching methods or student learning.

An interesting additional result was that while both C- and NC-groups reported high expectations for allowing their students to struggle when working through mathematical problems, the expectations they reported for themselves, although also relatively high, were lower than for their students. In essence, they reported lower tolerance for personal persistence with problem solving for themselves than for their students.

Based on these preliminary findings, we are continuing to analyze the data and to expand the study to include: further analysis of open-ended items, administration of surveys to additional PSTs, and interviewing of selected PSTs. The analysis of the interviews will allow us to better interpret survey responses and to dig deeper into their thinking and perceptions related to M-CK and M-PCK.

Our findings corroborate others (e.g., Ball, 2003; Ball, Lubienski, & Mewborn, 2001; NCTM, 2003) who have noted the importance of both M-CK *and* M-PCK for elementary school teachers. Our results suggest that one means of supporting elementary PSTs as they work to become effective mathematics teachers is participation in mathematics content courses that are designed specifically with elementary school teachers in mind. Indeed, these mathematical *content* courses may enhance learning outcomes of mathematics *methods* courses by providing sufficient M-CK to allow the PSTs to focus their attention, during *methods* courses, on the teaching methods and student learning related to the mathematics. Without these courses, the PSTs' attention toward student learning and mathematical teaching methods may be diluted while they are focusing on their own mathematical content knowledge. It will be important for future investigations to continue to investigate the influences of such courses on M-CK and M-PCK.

Endnotes

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