Pre-service teachers experiences with advanced digital technologies: The interplay between technology in a pre-service classroom and in field placements.*[1]

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Introduction

This paper reports on a study of a group of 20 pre-service teachers enrolled in a first-semester mathematics teaching methods course. Course activities included participation in two separate field experiences in neighboring school districts. The methods class placed considerable emphasis on the use of advanced digital technologies in the teaching and learning of mathematics, with particularly extensive use of the TI-Nspire. The field experiences varied in the extent to which technology was used from virtually nil in some classrooms to full implementation in others.

The methods course in which the pre-service teachers in this study participated was designed to introduce candidates to inquiry-based learning with open-ended questioning. The course proceeded from the premise that the use of advanced digital technologies can be a useful method for teaching in such a manner. In our experience, pre-service teachers generally fall into three categories with regard to their beliefs regarding the utilization of technology in mathematics classrooms: (i) "naysayers" who would like to minimise use of technology; (ii) "Yes, buts" who believe that students should learn concepts first and only then have access to technology; and (iii) "Yes, ands" who believe that technology should be used as an integral part of learning concepts. As pre-service teachers are developing a teaching identity it is interesting to observe the influences that push them in one direction or another. It seems to remain the case that most pre-service teachers have achieved their own mathematical success by being proficient in traditional environments (especially at the college level where use of technology is often outrightly discouraged) and, therefore, tend, in our experience, to be either "naysayers" or "yes, buts." Educators generally do not fall naturally into the third position without some coaxing, and the methods course was taught in a manner which might persuade the pre-service teachers to, at least, consider this position.

The data of our study shows that the methods class and the field placements served to challenge the pre-service teachers to clarify where they stand in this categorisation and what they imagine the place of technology to be in their future careers as mathematics teachers.

The principal conclusion of the study is the crucial, perhaps, decisive effect that modeling of exemplary practice in the field placement has on candidate attitudes regarding the use of advanced digital technologies in their teaching, that is to say, in creating the possibility that they may become "Yes, ands." Many of the preservice teachers in this study were resistant to the extent of the emphasis on technology in the methods class but, with one exception, students whose field placement was in a school where technology was used extensively developed a positive attitude to technology. Not surprisingly, candidates with positive technology-oriented experiences in the field express stronger desires to incorporate technology into their own teaching. There is evidence that the pre-service teachers' experiences in the classroom primed them for the possibilities of technology but it takes the experiencing of exemplary practice to convince them of the benefits of working to incorporate technology in their own teaching.

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A secondary conclusion is that while there was a general improvement in the quality of the lesson plans written by the pre-service teachers as the semester progressed, the lesson plans written by those students with field placements in technology-rich environments showed more sophistication, not just in the use of technology, but in terms of implementing inquiry-based and open-ended instructional approaches.

Research question

Through the use of the TI-Nspire in the methods course, we examined teachers relationship to, and use of, the TI-Nspire and other advanced digital technologies along the following dimensions: (a) the role of technology in the teaching and learning of high school mathematics; (b) the role of inquiry in the teaching and learning of mathematics in technology-rich environments; and (c) the implementation of technology-rich lesson plans/units in classrooms.

Specifically we examined the pre-service teachers' evolving attitude to the use of advanced digital technologies in teaching and learning mathematics, particularly in relation to the influence of their field placement. We also studied pre-service teachers design of technology-rich lessons and the extent to which these lessons promoted inquiry and learning for understanding.

Theoretical context

There is a growing body of research which indicates that digital technologies, including graphing calculators and CAS-enabled calculators, can enhance young students' conceptual and procedural knowledge of mathematics (Dunham, 2000; Thompson and Senk, 2001). Research has also shown the benefits to students of dynamically linked representations (Kaput, 1994; Rich, 1996) whereby upon altering a given representation, every other representation is automatically updated to reflect the same change.

As technology has become more sophisticated and functionalities of hand-held calculators have increased dramatically, there is a need for research that explores the extent to which teachers are able to employ technology effectively (Koehler & Mishra, 2005; Niess, 2005) and the extent to which students are able to work effectively in such technology-rich environments (Edwards, 2004; Meagher & Brown, 2007).

After Shulman's (1986) analysis of teachers' knowledge as a complex structure including content knowledge, pedagogical knowledge, and his introduction of the concept of pedagogical content knowledge, the research in this topic has become effectively grounded on his framework. With Mishra and Koehler's (2006, Koehler & Mishra, 2005) and Niess' (2005, 2006, 2007) introduction of the concept of the teachers' Technological Pedagogical Content Knowledge (TPCK), technology-related research in the teachers' professional development and education field has gained a new rich conceptual framework or "an analytic lens for studying the development of teacher knowledge about educational technology" (Mishra & Koehler, 2006, p. 1041). The TPCK model involves the content knowledge, the pedagogical knowledge, and the technology knowledge required to teach in technologically-rich environments (see Figure 1). Furthermore, the TPCK model discusses the combination of that basis knowledge such as technological content knowledge (TCK) versus technological pedagogical knowledge (TPK). For TPK, Mishra & Koehler (2006) discuss TCK as follows "teachers need to know not just the subject matter they teach but also the manner in which the subject matter can be changed by the application of technology." (p.1028). On the other hand, "technological pedagogical knowledge (TPK) is knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies" (Mishra & Koehler, 2006, p. 1028). Finally technological pedagogical content knowledge, according to Mishra and Koehler (2006) is:

> the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones (p.1029).

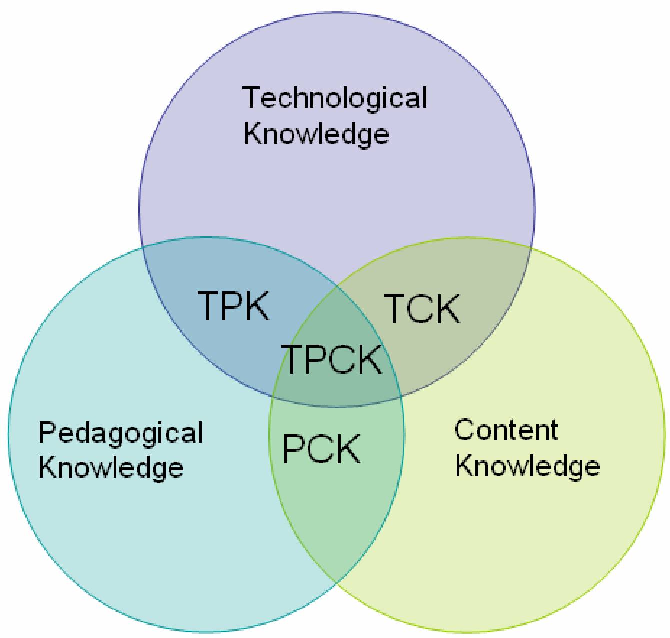

Figure 1. Re-creation of Mishra & Koehler's TPCK Model

Clearly, there is much to consider when studying pre- and in-service teachers' knowledge, views, beliefs, attitudes, and decisions about the use of technology in their classroom. Niess (2006, 2007) discussed how teachers' beliefs about teaching mathematics with technology play a crucial role in the development of TPCK. Moreover, Niess (2005) explained that there are four basic components of TPCK:

> 1. An overarching conception of what it means to teach a particular subject such as mathematics integrating technology in the learning.
> 2. Knowledge of instructional strategies and representations for teaching particular mathematical topics with technology.
> 3. Knowledge of students' understandings, thinking, and learning with technology in a subject such as mathematics.
> 4. Knowledge of curriculum and curriculum materials that integrates technology with learning mathematics(p.197).

Increasingly pre-service teachers are asked to incorporate technology into their teaching (NCTM, 2000). The extent to which they are willing or able to do so is influenced by a number of factors including their own experience with technology, constraints imposed by their teaching placements, and the quality of their training in the technology (Bullock, 2004; Moursund & Bielefeldt, 1999).

Data Collection

The pre-service teachers (n=20) were engaged in routine activities that comprise a mathematics teaching methods course at a small Midwestern university and were using the TI-Nspire handheld regularly. The course was designed specifically for pre-service secondary school mathematics teachers, with the subjects engaging in activities focused primarily on pedagogical issues (e.g. constructing lesson plans and grading rubrics, creating technology-oriented math activities) and content issues (solving mathematics problems, assessing student work).

Specific activities included

- Field Experience Reports: On two separate occasions, candidates researched, developed, and implemented mathematics lessons as part of the field teaching component of the class. The first critique focused on student behavior, teacher/candidate interactions, and instructional effectiveness. The second critique focuses on problem-posing and analysis of student mathematical thinking.
- Activity Writeups: The teachers submitted five secondary grades math activities that they constructed (either wholly original or modified from pre-existing materials). The teachers were encouraged to use these materials in their field teaching (if possible).
- Graphing Calculator Teaching Project: Candidates conducted original research dealing with the teaching of a secondary mathematics problem (or set of related problems) using the TI-Nspire graphing calculator. The problem(s) selected for study were subject to instructor approval to be well-suited for study with graphing calculators. The research was to meaningfully include the TI-Nspire in the investigation of the problem(s).

In addition to the routine activities of the methods class, the preservice teachers completed a *Mathematics Technology Attitudes Survey* and three short surveys, each of which consists of a mixture of multiple choice and open-ended items (administered electronically in weeks 4, 8, and 13 of the study). Finally they completed an open-ended exit survey with more general questions than those asked in the Week 4, 8, and 13 surveys.)

Data Analysis and discussion

Our analysis of the data focuses on two principal dimensions: (i) the interplay between the effects of the methods class and of the field placement on the pre-service teachers' experiences of and attitudes to technology, and (ii) the evolution of the pre-service teachers' lesson plans over the course of the semester. This analysis will be preceded by a look at the pre-service teachers' attitudes to technology.

General attitudes toward Teaching and Learning Mathematics with Technology

The Weeks 4, 8 and 13 surveys proved useful in tracking the general attitudes of the pre-service teachers to the use of technology. In the pre-survey, there were Likert type questions (1: Strongly Disagree, 2: Disagree, 3: Agree, 4: Strongly Agree) addressing this issue. (see Table 2).

On the pre-survey instrument, ninety percent of the pre-service teachers agreed or strongly agreed that graphing calculators help them understand mathematics and work on exams. These percentages increased to 95% in the post survey. In addition, a clear majority of the subjects agreed or strongly agreed that graphing calculators increase their desire to do mathematics (73% in the pre-survey and 65% in the post survey). It can be concluded, therefore, that almost none of the pre-service teachers were naysayers.

Other results in the survey suggest that there is quite a strong leaning in the directions of "yes, ands" at the beginning of the course. For example, eighty-six percent of them agreed or strongly agreed that graphing calculators are a useful support for discovering algebraic rules and the graphing calculator is useful because it allows people to look at the same problem in more than one way at the beginning of the study. These percentages increased to 90% and 95% respectively at the end of the study.

However, we perceive an effect through the methods course and field experiences that the pre-service teachers are, perhaps, becoming clearer in articulating where exactly they stand on technology use. An illustration of this is the fact that eighty-two percent of the pre-service teachers agreed that graphing calculators help people who have difficulties with algebra to still be able to do mathematics in the pre-survey. However, this percentage decreased to 70% in the post survey suggesting that some pre-service teachers were acknowledging a "yes, but" identity.

We see more of a "yes, but" identity in the pre-service teachers' stance that they need to know skills independent of calculator use. Ninety-one percent of the pre-service teachers in the pre-survey and 90% of them in the post survey stated that they need to know how to compute because the calculator won't do everything for them. All of them agreed that the graphing calculator is a useful tool to check their work both in the pre-and post surveys. However, the picture is not so simple as many of the pre-service teachers use calculators in the process of working mathematically: eighty-two percent of them at the beginning of the study and 90% of them at the end of the study agreed or strongly agreed that the graphing calculator helps them to get an idea of the result of a calculation before doing it.

Interestingly there were no statistically significant differences in students' attitudes toward teaching and learning mathematics with technology between the beginning of the study and the end of the study except one item—people who have difficulties with algebra have the same difficulties-even with a calculator [$t(19) = -2.939, p < .05$] [$Z=-2.486, p < .05$]. Sixty-five percent of the pre-service teachers agreed or strongly agreed with this statement in the post survey; however, 68% of them disagreed with this statement in the pre-survey. This suggests a switch, in this item, from a "yes, but" to a "yes, and" stance.

The interplay between the methods class and the field placement

Learning in the class vs learning in the field

Looking at the general trend, we observe that pre-service teachers' university class provided more experience for them in learning technology skills, critical thinking about technology, thinking about the mathematics content, as well as thinking and working with technology. The field experience, on the other hand, helped them more in reflecting on teaching methods (see Figure 2). Many pre-service teachers agreed that they were learning a lot of practical technology skills that they can use in their methods class sessions (Mean=5.9) and in their field placement (Mean=4.7) Most of them also (strongly) agreed that methods class activities made them think more critically about technology than before (Mean=6.1), which suggests that the students were moving towards more clearly establishing a position on the use of technology in teaching and learning mathematics. Even though more than half agreed that their field placement also helped them think critically about technology approximately, thirty eight percent of respondents disagreed or were not sure about this. This is most likely a reflection of the fact that in many of their placements (particularly the first placement) the pre-service teachers were exposed to little or no technology. This is further reflected in the fact that their class (Mean=6) was more helpful in requiring them to think and work a lot with technology as they design teaching activities than their field replacement (Mean=4.31). Approximately fifty five percent of pre-service teachers were not sure or disagreed that their field experiment helped them to think about technology when they design activities.

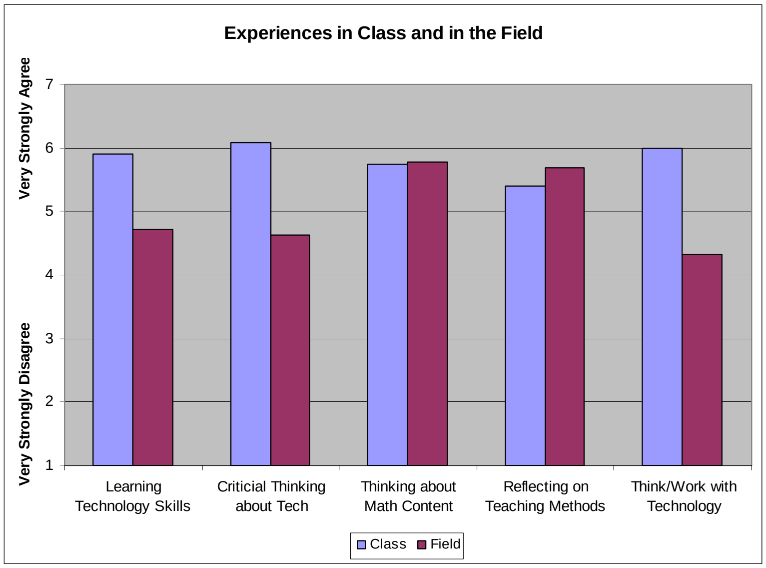

Figure 2. Experiences in the Field

When asked, in the open-ended prompts, to discuss the technological skills they were learning which would be useful in their future teaching, the pre-service teachers responses changed over time. At Week 4, eight pre-service teachers mentioned that they really liked TI-Nspire calculators:

> Being able to use the Nspire calculators is extremely cool. We are some of the first people to use these calculators and our experience with them will be invaluable. We've also been exposed to the TI-Nspire calculator. I am amazed by this. The amount of things you can do on this is incredible. However, the thing that appeals to me most about this calculator is that it is something a student can carry around with them. What I mean is that the calculator has features that reflect Microsoft Excel and Geometer's Sketchpad. For a student to have that access in the classroom that doesn't have computers would be great.

Two of the pre-service teachers discussed their worries that they were learning about this new technology but it was likely that they would not have an access to the calculators when they are teaching in future: “The big question I have is whether the school/district I am in will have access to these tools and technologies. Working with a graphing calculator or even a more advanced calculator like the Nspire is great, but will our students have them, or have access to them?” The other technologies that they discussed at week 4 were Smartboard (n=8), websites (n=4), Sketchpad (n=1). However, by week 8, no one discussed TI-Nspire calculators. Many of them were discussing the little access that they had to advanced technology in the field: “After going out in the field, I believe more than I did before that the technology I am learning to base my lessons off of, though, is far too advanced.” Many students reported exploring free resources that Internet offers.

The influence of the field placement
Looking at the open-ended exit survey we see a correlation between the pre-service teachers' field placement and their disposition to the use of technology in the future. Despite the emphasis placed on technology in the methods class, half of the students whose field placements had minimal or no technology did not develop a positive attitude to the use of technology in the teaching and learning of mathematics. One teacher who commented that "I found that my field teachers did not use technology in their classroom. I found their teaching methods to be more practical, and I will probably lean more towards their style," had said about the technology that "I found the TI-Nspire to be too complicated and not worth the hassle figuring it all out. I spent more time trying to figure out how to use it than I did learning about math." On the other hand, almost all of the teachers (there was one exception) who had been exposed to exemplary practice in technology-rich environments were eager to incorporate technology in their future practice. One student commented "My two field experiences were on different ends of the technology spectrum. One school barely had any technology and the other school had a lot." These two experiences resulted in this student declaring that "I am now more likely to use technology in my teaching. Technology offers so many advances for students and can relate to many different learning styles." Another student commented that "I will definitely want to use technology" having been in a school where "there was a grant for TI-89s in one class, for laptops in another and … their teacher was proficient in all of these technologies."

It can be difficult for the students to make the connection between the practices developed and encouraged in their methods classes without exemplary experiences in classroom of how these ideas can be put into practice. The students who made comments such as "I am less likely because of un-user friendly the TI-Nspire was," were not students who saw the TI-Nspire being used in a classroom. This correlation between the development of a positive disposition toward teaching with technology and exemplary experiences in a technology-rich environment calls for the development of a closer school-university partnership to allow students to make meaningful connections between their methods classes and he reality of classrooms.

We can see some particulars of hardening stances on the "yes, but"/"yes, and" axis in the week 13 survey. Approximately seventy percent of the pre-service teachers agreed that they would like use, specifically, the Nspire in future, when they become a full-time teacher. However, on the more general question of the place of technology in the mathematics classroom, approximately seventy percent of the pre-service teachers agreed that students should not use calculators until they have thoroughly mastered the required skills by hand. Sixty eight percent of them disagreed that seeing more than one way to do a problem typically confuses students.

Instructional practice and the relationship between teaching methods, content and technology.
It is interesting to observe differences in how the pre-service teachers think about technology for *their own use* in learning mathematics and what they think is appropriate *for their students*. In the pre-survey, ninety percent of the pre-service teachers agreed that graphing calculators help them understand mathematics and work on exams, and seventy three percent of them agreed that graphing calculators increase their desire to do mathematics. However, an analysis of the pre-service teachers' statements about instructional practice show the "Yes, but" camp holding sway. One pre-service teacher characterised this by arguing that "When kids are younger and inexperienced, they need to be taught the basics using direct instruction like I was. Now that I know some things, I can use the calculator to learn more. But I have a good foundation in the basics FIRST." Some were in the "Yes, and" camp, for example one pre-service teacher argued that "technology can make it easier

to test conjectures. For instance, with Sketchpad, we can test countless conjectures much more quickly than possible when using pencil and paper. When we observe behaviors in Sketchpad (or with the Nspire), students are more motivated to ask 'does this always happen?'" However, reservations about technology were more prevalent. The "yes, but" approach is all but defined by the pre-service teacher who comments that "technology doesn't change the way kids learn math. They have to learn it the way I learned it, by repetition and practice." Another pre-service teacher characterised this attitude stating that "Kids learn the alphabet song to memorize the letters. They use PEMDAS to memorize order of operations. They memorize FOIL BY HAND to learn about multiplication in algebra. After kids learn HOW . . . then they are in a position to learn WHY."

Some pre-service teachers did see the use of technology as challenging the current curriculum. "Technology does change the content. There are things that I studied in school that don't seem relevant in algebra class anymore. For instance, factoring. We did an assignment on the Nspire that showed that 99% (or more) of quadratics aren't factorable. So why do we spend all of this time factoring?" This attitude was, however, something of an anomaly. An overarching "Yes, but" attitude goes through much of the pre-service teachers' responses. There is strong evidence of a philosophical disposition that the teaching and learning of mathematics precedes/is prior to the use of technology and while technology can be useful it is not imbricated with teaching and learning. As one pre-service teacher puts it: "I'm not convinced that technology should influence content taught or pedagogy. But I do think that the content and pedagogy should influence technology."

Lesson Plans

Lesson plans were written by the students at four different stages in the semester: two before their field placements, one between the first and second field placements and one in conjunction with the second field placement The lesson plans were scored along three dimensions: Implementation of Technology [Active (1); Neutral (0); Passive (-1)]; Implementation of Inquiry Based Methods (Adapted from Northwest Regional Educational Library (NWREL - http://www.nwrel.org/msec/science_inq/answers.html)
[Student initiated (1); Guided inquiry (0); Structured Inquiry (-1)]; and Quality of Problem Solving [Active (1); Neutral (0); Passive (-1)]. See Appendix 1 for the full rubric.

Analysis of the scores showed that the students struggled along all three dimensions but improved in all three areas as the semester progressed.

	Technology	Inquiry	Problem Solving
Lesson 1	-0.25	-0.5	0.25
Lesson 2	-0.5	-0.375	0.125
Lesson 3	-0.25	-0.125	0.5
Lesson 4	-0.125	-0.375	-0.125
Lesson 5	0	-0.25	0.375

The first two sets of lesson plans were generally poor and reflected the fact that novice pre-service teachers constructed the materials. The second set show some improvement over the first but are still very teacher-centred. Several of the lesson plans explicitly use language such as "the teacher will lead students …" In most of these lessons, technology still seems like an afterthought for most teacher candidates, an "add on" rather than a tool to drive instruction. The third set of lesson plans, while far from high in quality, show marked improvement over the first two sets. This highlights the growing experience of the students and is reflective of the fact that these lessons were written after the first field placement.

The students' use of technology was very slow to develop and, before the second field placement, the use of technology in the lesson plans is not very sophisticated. For example, the use of Dynamic Geometry Systems (DGS) in the set of lessons focused on the Pythagorean Theorem, most of the pre-service teachers only require students to draw a particular instance of a problem rather than using DGS to generalize and/or form conjectures. It is further noteworthy that in the set of lesson plans where the use of technology was optional, several students chose not to use technology at all while other suggest the use of technology for "High Level kids only." Those that did employ technology in their lesson plans tend to focus on "what buttons to press" rather than rich opportunities for student discovery.

There is a rather sharp improvement in the student scores on Lesson 5. At one level this is unsurprising as one might expect the students to reach a maturity point late in the semester. We argue however for a more significant factor: the second field placement during which Lesson 5 was written. Support for this thesis is borne out when the scores for the lesson plans are disaggregated into two groups: those that had a minimal technology second field placement (MT) and those that had a technology-rich second field placement (TR):

	Technology		Inquiry		Problem Solving	
	MT	TR	MT	TR	MT	TR
Lesson 1	-0.25	-0.25	0	-0.5	0	0.5
Lesson 2	0	-0.75	-0.25	-0.5	0.25	0
Lesson 3	-0.25	-0.25	0	-0.25	0.5	0.5
Lesson 4	0	-0.25	-0.25	-0.5	0.25	-0.5
Lesson 5	-0.25	0.5	-0.5	0	-0.125	1

The lesson plan scores for both sets of teachers are similar for the first four lessons. There is, however, a quite dramatic difference in Lesson 5. The teachers in technology-rich field placements score much higher in the use of technology, which is to be expected but, significantly, they score higher in Implementation of Inquiry Based Methods and much higher in Quality of Problem Solving. In the presence of technology, they developed more pedagogically sound activities and their TPK (technological pedagogical knowledge) was clearly developing.

A significant feature of the lesson plans written in the technology-rich environment is that the tasks were formulated so that the use of technology was a necessary component of the lesson i.e. the tasks were designed assuming access to and ability to use technology. For example, one pre-service teacher designed a lesson centred around the classic birthday problem which involved the use of repeated simulations on the graphing calculator. This would be virtually impossible to replicate in a single classroom without technology. Another candidate posed a problem to students involving systems of inequalities. In the lesson, students attempted to construct a closed region satisfying the following constraints using TI-Nspire:
1. The system includes at least four linear inequalities
2. The graph of the system generates closed region
3. At least one pair of lines in the system is perpendicular

4. Every line has to have slope (i.e. not zero or undefined slope)
This lesson was markedly richer than this students' previous lesson plans, not just in the use of technology but in terms of inquiry-based teaching and problem solving.

We argue that an important element in the pre-service teachers developing calculator active tasks, perhaps becoming "Yes, ands" is their placement in a technology-rich environment. The modeling of exemplary practice and the mentorship available to them was, we believe, significant in this move. As one pre-service teacher commented on his placement in his Field Report:

> "Overall, this class [i.e. the field placement class] had many students eager to work with the new technology. It was exciting to enter the classroom at a point when new and innovative techniques are being introduced and see the results the calculators had not only on the willingness of students to engage in the material, but also on their abilities to construct good solutions to challenging problems. I hope that more students will have access to this new technology in the future to fuel new mathematic interest, just as the Nspires did for the students in Mr. C's class."

Technology in task design
It is interesting to compare the analysis of the Lesson Plans with the pre-service teachers responses when they were asked in the surveys to discuss the extent to which they were thinking and working with technology as they design activities. Several pre-service teachers mentioned and complained that the use of TI-Nspire was *required* at Week 4. However, others stated that they liked working with TI-Nspire and it capabilities: "I have been able to incorporate things such as the TI Nspire and GSP into my activity write-ups, and I think that incorporating these types of technology into lessons helps to make them more multifaceted and thus easier for a larger percentage of the students in a classroom to understand." Again here this student was considering students' learning with the help of technology. S/he was reflecting on her TPK. There were two pre-service teachers expressed how working with technology made a change in her desire to use technology more in her activity write-ups:

> I am using technology because we are required to do so. However, the second activity write-up used the TI-Nspire extensively because I thought it would be really neat to see if I could use it for my idea.
>
> At first, the activity seemed to me that we had to use and had to incorporate technology in our activity. Now is seems that technology is more of a tool to help us design a really good hands on, visual activity.

Many said that they were not learning about mathematics content as they design activities. However, one pre-service teacher mentioned that s/he was focusing on the why question more: "I feel as though I am not learning new mathematics content, but instead, I am thinking of what I already know in a different light. The class has caused me to think more about the why than the how, and to me, that is, the most important element of being a mathematics teacher." This student was reflecting on interaction between the mathematics content and the technology, i.e. TCK component of TPCK model.

When pre-service teachers were asked to discuss the pedagogical issues as they designed activities at Week 4, only two pre-service teachers mentioned the use of technology, one TI-Nspire and Websites. Other than that they mainly discussed the use of manipulatives, inquiry, problem solving, differentiation, and so on. After having some field experiences at Week 8, one pre-service teacher discussed how students were dependent on calculators for computation. Another pre-service teacher questioned her ability to use technology in the actual classroom:

> Our assignments have required us to determine how to incorporate the use of technology in the lesson… In doing this, one of the issues I've struggled with is the extent we would use technology. A number of cases in using technology have required extensive knowledge/experience with the technology. My question is whether we will practically get students to that level of proficiency where a piece of technology can be used. An even bigger question is whether students would have this technology available to them. My first field experience had no capability for students to use any sort of technology beyond a poorly designed calculator.

The pre-service teachers had, of course, seen many activities in the methods class by this stage which showed the possibilities for advanced digital technologies in the class but without a model of exemplary practice the teacher quoted here was struggling with how they themselves could actualise this practice.

Evolving Attitudes and Views over Time

To complete the analysis we look at pre-service teachers' responses over time, and observe that they strongly agreed that their methods class provided experiences in learning technology skills, thinking about mathematics content, reflecting on teaching methods, and thinking and working with technology at the beginning (week 4) and at the end (week 13), but just agreed at week 8 (see Table 1). However, the effect of their methods class on critical thinking about technology followed the increasing trend throughout weeks. Conversely, the pre-service teachers agreed that their field placement helped them in learning technology skills and critical thinking about technology at week 8 but not so sure at weeks 4 and 13. Results of One-way ANOVA showed that there were significant differences among the three weeks for methods class helping them: learning technology skills ($F(2,41)=4.38$, $p<.05$) , thinking and working with mathematics content ($F(2,41)=3.456$, $p<.05$), and teaching methods ($F(2,41)=4.08$, $p<.05$). The sharp decrease in week 8 might have caused those significant differences.

Considering their views on their methods class and field placement helping them to think about interactions among technology, mathematics and teaching methods, we observed that their university class helped them to consider those interactions more than their field replacement (see Table 1). From week 4 to week 8, there was an increasing trend in both university class and field replacement helping them to think about those interactions. However, at week 13 they did not agree that strongly that their class and field replacement helped them to think about interactions among teaching, technology and mathematics (see Table 1).

Experiences in the Class and the Field	**Class**			**Field**		
	Week 4	**Week 8**	**Week 13**	**Week 4**	**Week 8**	**Week 13**
Learning Technology Skills	6.15	5.40	6.22	4.65	5.00	4.44
Critical Thinking about Technology	6.00	6.07	6.33	4.45	5.00	4.44
Thinking about Math Content	6.00	5.20	6.11	5.85	5.80	5.56
Reflecting on Teaching Methods	5.55	4.80	6.11	5.80	5.73	5.33
Think/Work with Technology	6.05	5.80	6.22	4.50	4.00	4.44
Interactions among Technology, Mathematics and Teaching	**Class**			**Field**		
	Week 4	**Week 8**	**Week 13**	**Week 4**	**Week 8**	**Week 13**
Technology & Math Content	5.65	5.93	5.22	4.53	4.93	4.11
Teaching & Math Content	5.58	6.00	5.33	5.55	5.80	4.56
Teaching & Technology	5.47	5.80	5.44	4.68	5.40	4.22
Teaching Philosophy	**Week 4**	**Week 8**	**Week 13**			
Would Like to Use Nspire in Future	4.84	5.13	4.89			

Need to Know Enough Math	4.21	4.73	4.89
Knowing Why More Important	5.00	5.40	4.56
Use Calculators After Mastering the Skills by hand	5.05	6.13	4.00
Seeing More than One Way Confuses Students	3.11	3.20	3.67

Table1. Pre-service Teachers' Attitudes and Views over Time

Similarly, they strongly agreed that they would like to use TI-Nspire in their future teaching at week 8 but were not sure or just agreed at weeks 4 and 13. They increasingly agreed that they need to know enough mathematics to answer all of their students' questions from week 4 to week 13. They also agreed that students should not use calculators until they have thoroughly mastered the required skills by hand at week 4 and strongly agreed with that statement at week 8; however, they were not sure about that at week 13 (see Table 1). Those changes in their level of agreement with this statement over three weeks, resulted in significant difference among three weeks ($F(2,41)=6.55$, $p<.05$). This result shows that by the end of the course there was a growing "Yes, and" attitude to technology.

Conclusions and future directions

The overall conclusions of this study are that (a) if pre-service teachers' are to develop a positive attitude to the use of advanced digital technologies in their instructional practice they require more than a methods class to develop TPCK and that modeling of exemplary practice in the field placement has a crucial, perhaps, decisive effect on the students attitude and (b) that the most significant improvement in the quality of the pre-service teachers' lesson plans, in terms of being inquiry-based and open-ended, came when students had field placements in technology-rich environments.

This significant influence of the field placement suggests further direction for research. Specifically it calls for the development of school university partnerships so that students can engage in the following learning cycle: (i) A class of preservice high school teachers will work with the TI-Nspire to develop lessons/short units designed for technology-rich environments; (ii) experienced inservice will review the lessons/short units and present an initial redesign; (iii) the inservice teachers will teach the lessons, observed by the preservice teachers; (iv) the preservice teachers and inservice teachers will meet together to reflect on and redesign the lesson based on their experiences in the classroom. Engagement in such a cycle allows students to gain the benefit of exemplary practice in task design and use of advanced digital technologies and allows them to focus on this aspect of practice without having to also deal with the early pedagogical aspects which arise from teaching the class themselves i.e. classroom management, questioning etc.

We believe that the implementation of such a cycle in conjunction with a methods class would allow students to develop a more inquiry-based approach to their teaching and to see how the use of advanced digital technologies can facilitate that approach.

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