Tackling Low-level Cognitive Task Teaching in Secondary Mathematics: An Approach to Shaping Preservice Teachers' Preconceived Beliefs

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This article focuses on a secondary mathematics teacher education program where traditional field placements are prevalent in grades 9-12. Traditional, for this article, is defined as and comprised of: (a) straight-rowed desks in classrooms, (b) explicitly direct instruction (teacher-centered classrooms), (c) predominantly repetition of low-level cognitive tasks, and (d) consistent absence of technology use by students to explore mathematics concepts and problem solving. This article aims to inform readers of how one secondary mathematics teacher education program is addressing the challenges many programs currently experience in producing new teachers of best practice through advanced mathematical tasks and advanced technology use for teaching mathematics within education courses. Early evidence appears to be having effects on some pre-service teachers pre-conceived beliefs about teaching mathematics traditionally with greater anticipation for long-term sustainable change.

Introduction

In today's arena of high stakes testing and accountability, quandaries exist for secondary mathematics teacher education programs (TEP). Though there are many to address, this article focuses on three specific issues. First, many field experiences, practica, and student teaching experiences for secondary mathematics pre-service teachers in TEPs today occur in classrooms where they witness the *tests* as a large focus in their placement schools and classrooms. These experiences have resulted in many young pre-service teachers witnessing *mandated testing* as the driving force behind what and how to teach. Unfortunately, many of the questions on the [mostly multiple choice] *tests* involve primarily skill-based algorithmic processes or memorizing. According to Stein, Smith, Hennington, and Silver (2000), most of these test items would be classified as low-level cognitive demanding tasks. Second, some secondary mathematics pre-service teachers experienced their own high school mathematics studies fairly absent of emerging technologies for enhancing mathematical understanding while many pre-service teachers have preconceived beliefs that technology is not very essential in the teaching of mathematics (Leatham, 2007; McKinney & Frazier, 2008; Norton, McRobbie, & Cooper, 2000; Quinn, 1998). The third quandary focus in this article is the sizable number of pre-service teachers who rarely get to experience secondary mathematics curricula that embrace technology, time for students to explore high cognitive mathematics tasks, and student-centered instruction due to experiences in primarily traditional teacher-centered classrooms. Frykholm (1995) reported that the single greatest influence on shaping teaching practices of pre-service teachers is their cooperating teachers. Therefore, this article focuses on how one secondary mathematics program aims to educate and mold pre-service teachers into well-rounded, open-minded, future educators who synthesize, analyze *teaching to mandated tests*, and ultimately teach students how to become critical thinkers and advanced problem solvers through high cognitive mathematics tasks.

Framework for Program Objectives

Changing or molding pre-service teacher preconceived beliefs about teaching mathematics is a very complex task. Typically, beliefs and attitudes are primarily based on pre-service teachers' own experiences as students in the mathematics classroom (Feiman-Nemser, 2001; Frykholm, 1999) which encompasses years of developed views and values. A number of the tools discussed in this article to address these quandaries borrow and adapt approaches from the TIME 2000 Program framework (see Artzt & Curcio, 2003) among others' work (Frykholm, 2000; Kirtley & Olson, 2005; McClintock, O'Brien, & Jiang, 2005; Peressini et al, 2004; Qing, 2005; An, 2004; Watt, 2005). The current effort to open minds and reshape pre-service teachers' preconceived beliefs (see Ball, 1988; Beswick, 2006; Cady, Meier, & Lubinski, 2006) about teaching mathematics. Reshaping these beliefs into a teaching philosophy based on existing literature and TEP coursework experiences is a daunting task when traditional field placement experiences are most prevalent.

The program's efforts within coursework and field experiences encapsulates: a) The increasing of the rigor of mathematical assignments within mathematics education courses so that pre-service teachers reevaluate their own mathematical content knowledge; b) embracing NCTM's technology and equity principles as two guiding forces by examining findings within existing research and examining best practice journal articles; and c) incorporating the conclusions of Alan Schoenfeld (2002) who asserted that basic skills are not compromised by non-traditional classrooms because students in traditional and reform settings score equivalently [no significant difference] on basic skills test items. Further, Schoenfeld concluded that reform efforts consistently advance students' conceptual understanding and problem solving ability beyond traditional basic skills focus. Moreover, secondary mathematics TEP coursework includes aspects regarding Schoenfeld's final conclusion—amassing evidence is implying that the achievement gap can be closed between whites and lower achieving minorities using reform curricula [and teaching]. A number of research studies completed since 2002 reify Schoenfeld's conclusions (see Gutstein, 2003; Harwell et al, 2007; Reys et al, 2003; Schoen et al, 2003).

Within these daunting tasks underlies another long-term goal for graduates of the TEP. Cathy Seeley, former president of the National Council of Teachers of Mathematics (NCTM), encouraged teachers to become actively involved in the process as states write and revise their standards and tests. Moreover, it is beneficial if teachers participate in writing state test items rather than resisting testing or not participating altogether. In an interview with Shaughnessy (2005), Seeley stated, "American mathematics curricula have been appropriately labeled as *a mile wide and an inch deep*". Thus, as we tweak to improve secondary mathematics education and TEPs, we should arguably move at an angle that injects additional mathematical content exploration, investigates advanced problem solving, delves into multiple teaching methods, while integrating technological tools for advancing mathematical understanding with sound pedagogy. In theory, the methods used to employ the program's objectives are targeted to allow graduates of the TEP to become astute enough to participate in state assessment and standards work much earlier in their teaching careers than later. Graduating students will have experienced pedagogical methods allowing them to *challenge* their future students with higher-level cognitive mathematical tasks while still accomplishing the teaching of necessary skills. At the same time, future teachers are also learning to embrace technology as a tool for increasing mathematics understanding and success over using technology solely as a computational *black box* tool.

Secondary Mathematics Education TEP Overview: Coursework

The TEP presently consists of nine semester hours of mathematics education coursework interspersed with field experiences, assessment, reading, and other general professional study courses. While the author recognizes that many secondary mathematics TEPs unfortunately do not contain nine semester hours of mathematics education coursework, the author intends to disseminate some of the tactics employed within each course that could fit into mathematics content courses, general secondary education courses, and mathematics methods courses. Within the TEP program, pre-service teachers (PSTs) take their first mathematics education course during the fall semester of their junior year. PSTs then take the second course the following spring. The third course is methods during the final year prior to interning (see figure 1).

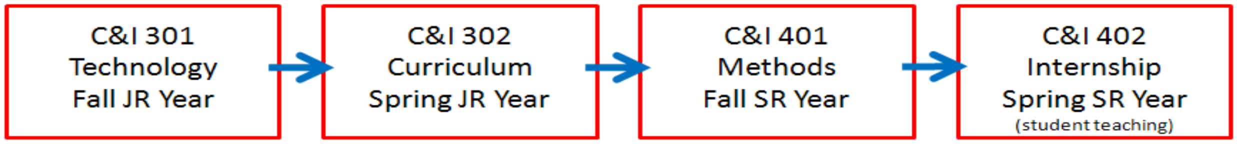

Figure 1. Mathematics education coursework sequence.

Additionally, students in the secondary mathematics TEP take a number of non-mathematics education specific courses, whose content spans special education, classroom diversity, general secondary education, social & educational foundations, and a few other topics. Mathematically, students complete the equivalent of a bachelor's degree in mathematics in the College of Arts & Sciences by completing 21 hours at the junior and senior levels, 15 hours at the freshmen and sophomore levels, a statistics course, and a computer-programming course. Graduates of the secondary mathematics education TEP receive a BS in secondary education with dual majors of secondary mathematics education and mathematics. Graduates are then recommended for a state teaching certificate[i] (grades 6-12) in mathematics.

Secondary Mathematics Education TEP Overview: Clinical Experiences

Prior to student teaching, PSTs experience at least 180 (most over 200) clinical hours of placements in a wide-variety of local classrooms before their student teaching which approaches an additional 600 hours. PSTs experience their first clinical placement in a general secondary education course. This placement consists of 30 hours completed in three or six hour increments in a local middle or high school mathematics classroom. For the typical student, this general secondary education course is completed either during the spring sophomore or fall junior semester. It is during this course that PSTs formally apply to the secondary mathematics TEP via a writing sample on an educational issue and an interview with faculty. An additional 10 to 12 hours of clinical experiences are completed within the special education course. The special education course examines, among other topics, special needs and inclusion issues. The curriculum course (see figure 1) consists of an 18-hour placement where PSTs begin to target whether they wish to do their student teaching in a middle or high school classroom. This is important prior to the senior fall methods course because the methods course placement is typically in a very different setting than the student teaching setting. This is so that PSTs get a wide variety of clinical school experiences at both the middle and secondary level. During the fall methods course, PSTs complete a minimum of 120 hours of clinical experiences either in a middle or high school classroom where three lessons are taught, observed by faculty, and evaluated. Thus, if a PST experiences a middle school placement during their methods course placement, they would more than likely have a high school placement for student teaching or vice-versa. The importance of PSTs to begin targeting the setting for their student teaching during the spring junior year is so that their placements can be arranged strategically for the fall senior methods placement.

Local School Settings

Most (not all) local school settings and teaching methods are more or less traditional teacher-centered classrooms. Program faculty estimate roughly four out of every five local mathematics (6-12) classrooms available for placement fit this description. Curricula within local middle and high school classrooms would be classified as traditional to semi-traditional sometimes classified or referred to as commercially developed curricula. No local middle or high school uses one of the standards-based curricula developed through NSF funding, though a state funded professional development program (PD) does incorporate lessons and materials from some of the NSF-funded and developed middle and secondary mathematics curricula. However, not many local cooperating high school mathematics teachers have participated or completed the state's PD. Thus, these modules or lessons sometimes end up as filler lessons in the classroom. A fair number of middle school mathematics teachers have participated in the PD and more high school teachers are planning to participate soon. All local high schools follow a block-schedule format while most middle schools have switched recently from block scheduling to period scheduling. Some middle schools follow an abbreviated schedule mixing both types. Core subjects may span a little more than an hour while non-core subjects may span less than an hour.

Within local schools, the use of technologies such as graphing calculators, dynamic geometry software, computers, computer algebra systems, and other technologies is skittish classroom to classroom. Two reasons are hypothesized as to why. Funding issues prevent some schools from obtaining such materials while low-SES students cannot afford to purchase technologies either. Second, most of the veteran teaching force obtained their formal teacher training well before the recent explosions of technologies for teaching mathematics and technology use in the teaching of mathematics was not part of their formal teacher education program. Prior to the No Child Left Behind Act, professional development for local teachers using technology was almost non-existent. Recently, a small number of local teachers have begun to embrace some technology and look to improve their knowledge of teaching mathematics with technology. Overall, technology is not employed by most teachers as a learning and inquiry tool but used almost solely as a computational checking tool.

Program faculty recognizes the challenges facing the development of a new breed of mathematics teachers in the current setting. Specifically, program faculty realizes that local school teachers, local curricula, and state testing has or will have the greatest impact on PST classroom practices. However, within the mathematics education coursework, program faculty has set forth the objectives previously discussed. Early results have been encouraging in a limited number of cases. The evolution of great mathematics teachers takes place well after college graduation. So, the three mathematics education courses discussed in this article aim to put PSTs in a setting conducive to recognizing great teaching of mathematics while setting the tone for early professional growth during student teaching and their first years in the classroom.

Secondary Mathematics Education Course Components: Technology Course

This course has three major objectives as the introductory mathematics education course for PSTs. First, to expose pre-service TEP candidates to technologies for teaching mathematics concepts via spreadsheets, dynamic geometry software, computer algebra systems (CAS), graphing calculators, data collection devices, and some free java-based applets available on the web. A large percentage [more than 50%] of PSTs in the secondary mathematics TEP have very limited, if any, experience with the use of technology other than for computational mathematics or button pushing for graphing. The second major objective of the technology course is to break down [subtlety] pre-conceived notions that teaching mathematics with technology is not essential by injecting rigorous (high level cognitive tasks as defined by Stein et al, 2000) mathematical tasks within course assignments. The final major objective is to introduce PSTs to NCTM’s

Principles and Standards for School Mathematics (PSSM) and the middle and high school teaching journals.

The first objective is covered during the onset of the class. Forty to 50% of the beginning of the course focuses on activities and instruction to learn how to operate each form of technology[ii], but also explores some mathematical topic from the middle school or high school curriculum. Time spent on each area of technology is dependent on the knowledge of the class as a whole. For example, typically all or most PSTs have no experience using motion detectors (data collection devices) connected to graphing calculators. Two activities spanning a total of two or three full weeks using the motion detectors deeply explore two topics appearing in the high school algebra curriculum. One activity focuses on discovering the mathematics behind the quadratic motion model $P(t) = -16\,t^2 + V_0\,t + P_0$ which can just magically appear in the algebra curriculum without deep explanations or exploration. The model simply is an equation to solve word problems in a homework set in most instances. To set the tone for this activity, students are first given a unique example of this equation and asked to *explain by writing* about their understanding of the –16, V_0, and P_0 constants (See Appendix A). Note: Task 2 is a loaded question since all units and references to the constants have been omitted purposely to create discourse. After many PSTs struggle with writing an explanation (five to ten minutes is given), a group discussion ensues on the topic. Most discussions center on the calculus topics of derivatives and anti-derivatives. Prompts then lead PSTs to discuss the constants without using calculus explanations. Here is where most PSTs begin to realize their knowledge of this quadratic model consists primarily of topical understanding only. They can use the quadratic model to solve directly stated problems, but cannot explain the model constants without calculus algorithms and rules. A few PSTs have even confessed they do not know why different values (–4.9 and –16) appear in book problems as the leading coefficients for the same types of problems.

After establishing the tone to address the second course objective, PSTs learn to use the motion detectors to record data through a modified version (see appendix A) of lesson 11 from *Real World Math Made Easy* (Brueningsen, Bower, Antinone, and Kerner, 2005). This lesson consists of recording data from dropping a basketball from some predetermined and measured height. Within the lesson, PSTs drop the ball from rest, give the ball a little push down, and do a little flip upwards. Dropping the ball from rest allows PSTs to discover the model constants –4.9 (and –16) and P_0 through examining one full bounce of data. Moreover, the initial velocity is also explored and discussed. Additionally, PSTs explore both representations (vertex and standard form) of quadratic functions.

This early lesson within the technology course has produced three emerging findings [see student evidence of professional growth presented later in this article]. First, some PSTs have reflected mathematics can be fun, interesting, engaging, and is not just about plugging and chugging. Second, PSTs have confessed in different ways their mathematics classroom experiences lacked the depth of knowledge needed to understand mathematical topics well. PSTs have recognized they have a lot to learn about mathematics topics and teaching those topics for understanding to all students. Last, PSTs have discovered that graphing calculators can be incorporated into the teaching of mathematics for more than just computational, answer getting, and graphing tasks [three preconceived beliefs about these handheld tools being used solely for such tasks].

Another component of the course focuses on using CAS in teaching mathematics. Early in the course, a written assignment is given to obtain the PSTs knowledge and beliefs concerning CAS. In some cases, PSTs confess they do not know what a CAS is or have not used one. For those with experience using CAS, their knowledge was obtained and limited to using a CAS in an AP calculus class in high school. In all instances but one, a CAS was not used prior to their AP calculus class. The lone exception was a PST from one of the two most affluent (high SES) high school districts in the state and purchased the CAS as a tool to check their homework prior to enrolling in calculus. After the written assignment early in the course but prior to a class focusing on CAS, students are required to read a *Mathematics Teacher* article (see Jakucyn & Kerr, 2002). Within this article, the authors describe their process of incorporating CAS in a pre-calculus course in their high school as a *white box* discovery tool as opposed to a *black box* tool for getting answers.

Initial CAS activities focus PSTs on learning the functionality of a CAS (syntax and commands of what CAS can actually do). As PSTs learn syntax and commands through activities such as a Pascal's Triangle activity (see figure 3 in Jakucyn & Kerr, 2002), the *white box* mathematics of CAS begins to emerge for PSTs. Mathematical discoveries set the tone to begin some higher cognitive tasks within another activity (see appendix B). Within this lesson, PSTs explore solving radical equations using the TI-Nspire CAS handheld (new in 09-10, Derive 6 used previously). In many high school mathematics classrooms, radical equations are typically solved step-by-step algebraically [squaring once or maybe twice, rarely cubing] and isolated from conceptual understanding of underlying mathematical connections. Rarely do local high school students explore the underlying mathematics of radical equations and are less likely to be provided a setting to make connections. This lesson was created within the technology course because most radical problems are *book cooked* and work out nicely. Rarely do students ever get the chance to understand why teachers tell students to *always check your answers* for radical problems solved algebraically. Most PSTs fail to demonstrate knowledge or explain why algebraic solutions to some radical problems have extraneous solutions and others do not. Rarely has a PST been able to generate an answer to the mathematical problem asked early in the course—Give a radical equation with one real solution and two different extraneous solutions. The CAS activity is designed to allow PSTs to take some of the focus off tedious symbolic manipulation of radical equations and focus on the concept of why radical equations have real and extraneous solutions. The TI-Nspire CAS capability expands the discovery learning opportunities beyond non-CAS handhelds. By the end of the radical lesson, PSTs demonstrate and express similar conclusions as discussed with the data collection device lesson.

While this article does not go into details of spreadsheet activities, dynamic geometry software activities, or online java-based applets, the approach in the technology course is the same as those discussed for CAS and data collection devices. The third objective of the technology course is addressed by PSTs becoming student members of NCTM and being given two assignments in which they read and reflect on a chosen lesson article from *Mathematics Teacher* and *Teaching Mathematics in the Middle School.* PSTs also review and discuss lessons posted on the NCTM website involving technology. The initial effort in the technology course to break down preconceived beliefs that teaching mathematics without technology is not necessarily essential seems to hit a nerve at times. PSTs in the course are presented with a series of mathematical tasks designed to reshape preconceived beliefs about teaching mathematics solely through low-level cognitive tasks by exposing PSTs' surface level understandings of particular topics. At times, the nerve is severed and a new view on mathematics emerges. Lessons and activities in the technology course also focus on demonstrating that without technology, teachers can easily fall into the trap of focusing on a small number of book-cooked questions that would be classified as low-level cognitive tasks (Stein et al, 2000). The technology course begins the process of challenging and re-molding beliefs about teaching mathematics as involving mostly rote algorithmic skills and memorization by injecting mathematical content that requires conceptual understanding and advanced problem solving strategies encompassing technology. Moreover, the course floods pre-service teachers with a wealth of different technologies that can increase their own mathematical understanding. In this arena, PSTs begin to realize how much more mathematical understanding can be accomplished in a classroom where instruction is augmented with technology and advanced problem solving for all students with different learning styles in a variety of mathematics courses.

Secondary Mathematics Education Course Components: Curriculum Course

In many placement schools for secondary pre-service teachers, traditional instruction and curricula are prevalent in field placements for students prior to their student teaching. Even when standards-based oriented texts are used as supplemental materials by placement schools after participating in the state PD, many cooperating teachers still focus almost exclusively on memorization and repetitive examples. Many teachers assign exclusively skill only type exercises for homework. The curriculum course provides a setting in which pre-service teachers can experience, learn about, and develop lessons using the broad spectrum of advanced curricula including curricula materials where high-level cognitive tasks are more evident than traditional commercially developed curricula. Three major course objectives exist in this curriculum course. First, the course utilizes part one of *Implementing Standards-Based Mathematics Instruction* by Stein et al (2000) to introduce formally the construct of low and high-level cognitive tasks. Although this book sometimes is used for professional development with in-service teachers, this course uses the book to introduce PSTs to this construct before their methods course and student teaching. Second, the course focuses on developing the skills necessary for young teachers to learn how to be resourceful to develop reform-based pedagogy and student-centered instruction into lessons embracing flexibility, reversibility, and generalization (see Confrey & Lanier, 1980; Rachlin, 1985). Typically, the primary source for lesson planning for new in-service teachers is a commercially developed curriculum. This type of setting is more prevalent in the schools where graduates begin their teaching career. Finally, the last major objective centers on the evaluation of the state standards and assessment items for algebra-1 and geometry. The standards and assessment are deeply examined, critiqued, and test items re-written when determined as poorly assessing a certain standard. The curriculum course is intended to maintain the technology course objectives by challenging preconceived notions about teaching mathematics and creating a setting conducive to advancing ideas on how to teach mathematics above the status-quo.

During the first month of the course, the first objective is the sole focus. PSTs are assigned to read part one of *Implementing Standards-Based Mathematics Instruction* by Stein et al (2000). The first class meeting after the reading assignment involves students reviewing mathematics problems and instructional tasks by labeling the problems and tasks as high or low-level cognitive mathematical tasks as defined in the reading. Many of these items come from state practice tests and NAEP released items. PSTs work in class together in groups for this assignment while the program faculty teaching the course plays the role of a facilitator. In most cases, PSTs realize this is a very difficult task and requires a deeper examination. For example, PSTs are presented the task to label some mathematics problems' task levels while giving a written rationale as to their choice. In most cases, PSTs within groups and within the class as a whole typically do not come to a consensus on all problems being labeled the same. Hence, a large amount of discourse ensues about items where a lot of variation exists. Once the class comes close in agreement on the tasks being labeled, PSTs are then confronted with analyzing and labeling a high school student's response to the mathematics problems where the cognitive level is much lower than originally intended. This is a loaded scenario preset to work out this way. What typically has ensued after introducing the student's answers to the problems is a great deal of discussion about the task levels being less than expected. This lesson is designed to open the eyes and mind of the PSTs about the fact that teachers may write perceived good math problems for an assessment. Later after students turn in the work, the teacher realizes the items failed to illicit or address the intended concept. Further, PSTs examine the idea that writing an advanced problem may end up completely missing the intended target so the class examines trying to foresee these issues.

Early in the curriculum course, PSTs are introduced formally to the construct of low and high-level cognitive tasks in a setting that promotes discourse. At the same time, opening minds to the fact that little learning is accomplished by only incorporating low-level cognitive tasks into teaching and assessment. The first month of the class sets the tone as the second major objective is addressed next.

The middle of the semester consists of a lesson enhancement project. First, students are presented in class and in groups an algebra-2 textbook being used locally in schools. Groups choose a topic of their choice for which they would like to write an advanced lesson to teach the topic. Groups sometimes choose topics for interest of the topic, perceived ease of teaching the topic, and possibility for incorporating technology. Groups who have chosen the later reason usually consist of PSTs who took a strong interest in the technology course the semester prior. Groups comprised of PSTs who typically *wait until the last minute to do things* choose what they think is an easy lesson to teach. For example, a group once chose the lesson of teaching *rules of exponents*. Although the state standard addressing this topic is housed in algebra-1, the algebra-2 textbooks typically include a section in the early part of the book for review purposes. At first, the faculty was confident this topic was chosen for the perceived ease of teaching by example. However, this group actually ended up with a very advanced lesson and assessment for the topic.

After topics are chosen (each group with a different topic), the groups are charged with writing a lesson plan for the topic using the secondary mathematics lesson plan template.[iii] The task is simple at first. Write your lesson plan using the template provided. Prepare your lesson for a 90-minute block period. Be specific and detail what you will demonstrate to your class, questions you will ask, describe the engaging instructional activities, state the homework you will assign, and anything else that fits into the lesson plan.

For the rest of this initial class meeting (typically once a week 2.75-hour meeting), groups spend their time writing their lesson plan using the algebra-2 text provided as a resource as if they were a new teacher in a school using this textbook. If a group does not finish during the class meeting time, their group is required to meet outside of class to finish their lesson plan before the next class meeting. In almost all instances, the initial lessons are solely direct instruction, teacher-centered lessons. However, this is expected so that lesson enhancements will take center stage the following week when the lesson assessment is used to drive the lesson revision. The backward design concept is derived from *Understanding by Design* (Wiggins & McTighe, 2005). The next week of the course charges the PSTs to develop their end of lesson assessment. However, the guidelines of the assessment must include a balance of low and high-level cognitive tasks. Additionally, reversibility and flexibility must also be incorporated into the lesson assessment[iv]. The most evident theme emerging from this task is PSTs realize their initial lessons almost always fail to provide a classroom setting that would teach for understanding. This is expected by the faculty. PSTs have confessed after finalizing their assessment that their lesson had not prepared their hypothetical class to understand but rather imitate. For example, the group's initial lesson on teaching rules of exponents was completely absent of anything but direct instruction and the showing repeated examples of each rule. However, this group ended up developing a very nice assessment incorporating a nice balance of low and high-level tasks, as well as incorporating flexibility and reversibility. Most importantly, the group realized they had to go back and re-write a large portion of their lesson because their end of lesson assessment would be a disaster otherwise.

This lesson enhancement activity utilizes the framework that good assessments will drive advanced teaching of mathematics and that poor, isolated low-level skills assessment can lead to *teaching to the test* at the expense of deeply examining the mathematical content (Erickson et al, 2007; Firestone, Monfils, & Schorr, 2003, 2004; Lamb, 2007). Therefore, as PSTs finish their meaningful lesson assessment, the groups are essentially *forced* to go back and *enhance* their initial lesson plans dramatically. At this point in the class, many PSTs are eager to learn how they can teach for deeper understanding of their chosen topics. Also, initial lessons [not great in most cases] and balanced assessments have been developed. Students take a *time out* from their lesson development and spend the next week of the class examining and working through lessons from three less than traditional[v] curricula than what their lessons began utilizing. Assessment items and tasks within lessons of these curricula are discussed. Moreover, PSTs are asked to answer some pre-selected mathematics problems from within each curriculum for a homework assignment. In some cases, PST work reflects limited knowledge of solving problems using flexibility and reversibility. In a few other cases, PST work exemplifies advanced knowledge of the mathematical content. In any case, lesson groups are required to utilize external resources [not just the three curricula mentioned] to *rewrite and enhance* their initial lesson to reflect advanced mathematical understanding that is required for doing well on their advanced lesson assessment.

The final major objective of the curriculum course is to examine the state standards (course of study) for algebra-1 and geometry, as well as to explore the nature of state test items that assess the standards. PSTs are assigned to groups for this portion of the course. Each group goes through the state standards first for algebra-1. The first task for the groups is to connect each standard to one or more sections within the algebra-1 textbook used by some local schools.

This task is designed to begin familiarizing PSTs with the state standards for algebra-1. Additionally, the program faculty has an objective not made transparent to the PSTs. That objective is to get PSTs to discover that commercially developed texts rarely are written specific to state standards and many sections in the text do not address any of the standards. When the discoveries are made, discourse ensues regarding *the thumb test* (teachers choosing texts) and how publishers put books together for multiple states (except for large states, for example, California, Texas, New York, etc). This discussion is very worthwhile and meaningful. In many cases, PSTs are shocked to learn how unaligned texts are with the state standards, even though the textbook has the state logo appearing on the binding! The second part of this assignment then examines the geometry standards and a local textbook. After each group is satisfied with both subjects, the class as a whole puts their work together and comes to a class consensus on each standard and at least two sections (if applicable) in the textbook addressing each standard. The final part of this component of the curriculum course examines released NAEP, state test items, and practice tests covering algebra-1 and geometry. Each group is required to identify 50-100 test items as to which standard the item is assessing. This is a major challenge at times. By working in groups, this task eventually ends up with good discussion and accomplishes a lot. Finally, groups are asked to identify questions that poorly assess a standard. For example, one standard states that students will be able to factor trinomials. Sample test items labeled by PSTs for assessing this standard are all multiple-choice items given a trinomial with four answers written as the product of two binomials. PSTs correctly identify an item such as this as poorly assessing the factoring standard because teachers can just teach students to distribute the answers to correctly answer a question in this format. In many instances, PSTs realize that *test-taking skills* overshadow actual assessment of the standards. PSTs are then eager to attempt to write a new assessment item. It is a difficult task for PSTs, but the eagerness of PSTs to attempt the task is a good sign for the developing teacher.

The lesson enhancement project is the largest component of the curriculum course but is not overshadowed by other curricular components of the course. The lesson enhancement project spans four to six weeks depending on the amount of discourse that ensues during class meetings. However, the emerging themes from the course are promising. PSTs are showing signs that teaching mathematics is more than just lecture, showing examples, and testing low-level cognitive skills. Moreover, some PSTs have demonstrated a respect for multiple solution methods as equal in value to problems once deemed by PSTs as paper and pencil only type problems. Technology within developed lessons is advanced for some PSTs at this point of their academic teacher preparation. Although not all PSTs have demonstrated high levels of professional growth, an encouraging number of PSTs have demonstrated growth and evidence they are reevaluating their beliefs about teaching mathematics (see evidence section for professional growth demonstration).

Secondary Mathematics Education Course Components: Methods

After one year of technology and curriculum educational coursework, PSTs begin their final year of studies. In the fall, PSTs enroll in the methods course, participate in over 120 hours of clinical placements in a local school, and begin to teach some mathematics lessons in local schools. One primary objective of the methods course is to address making mathematical connections across an entire unit of lessons. Within this objective, PSTs examine their own mathematical understanding across secondary topics. A second primary objective is requiring advanced lessons to be taught during clinical placements. Although there are other major course components, this article focuses on these two objectives because each has demonstrated professional growth for some PSTs beyond expectations. Further, the methods course is the culmination of coursework prior to student teaching and targets the professional growth aspect throughout the course. Additionally, PSTs attend the state affiliated NCTM fall forum to begin participation professionally with their future colleagues. While no methods course is perfect, this article continues the discourse regarding the challenge of creating a new breed of mathematics teacher in a traditional setting.

Local teachers identified some previous PSTs as being weak in their unit planning during student teaching. This weakness for a few PSTs in the past was one rationale for instituting the project focusing on unit plan development. In a survey of PSTs last year in methods, PSTs most common answer, when asked to define a unit of content, was a chapter in the textbook. This kind of answer is not surprising. The survey is given before a unit is ever explored deeply. The introduction to units during the methods course uses materials and approaches from two methods books (Brahier, 2005; Posamentier, Smith, & Stepelman, 2006). Brahier (2005, p.138) displays a concept map for a unit on linear functions. The concept map is examined and discourse on linear functions ensues. The discourse typically focuses mostly on the order in which to cover linear functions. Rarely do PSTs agree on a set order, but most have agreed that multiple representations of linear functions should be addressed in a way that students should be able to make connections. This is an improvement for PSTs since the technology course. Early in that course, the same group of PSTs rarely recognized graphical or tabular solutions to linear equations as being equivalent in value to the traditional algebraic paper and pencil solution. Most PSTs agree students should be able to solve linear equations using these three representations, but encouraging growth is represented by the fact that many PSTs have begun to recognize the equity of different solution methods. While unit planning and mathematical connections across a unit are foci in the methods course, the second objective in this article is of great concern.

During the methods course, PSTs begin their primary school placement. The previous year, PSTs experienced small clinical placements in middle or high schools. However, during the methods course alone, PSTs acquire over 120 clinical hours within a local school. While program faculty recognizes cooperating teachers will probably have greatest impact on the PSTs, the program faculty does require PSTs to teach at least one lesson [of their three evaluated teaching lessons] to incorporate technology and teaching via non-teacher centered direct instruction. Some cooperating teachers have met this requirement with skepticism or resistance, though some cooperating teachers have embraced this requirement with open arms. As part of the clinical field experiences (a three-hour equivalent course), the three lessons evaluated by program faculty have specific objectives including those regarding technology and instructional strategies. The mediating factor with less enthused cooperating teachers has been addressed by the fact that quality teaching standards are required to be evaluated within the clinical experiences teaching. Thus, essentially PSTs are required to incorporate technology and student-centered instruction into one of their three evaluated teaching lessons.

While the methods course and clinical placements continue to challenge status-quo teaching methods, the program faculty recognizes a long and enduring endeavor to develop and grow young PSTs into well-rounded mathematics teachers of best practice. The task is familiar to many secondary mathematics education programs, but this article aims to create a forum of exchange of ideas for handling such issues existing across the nation.

Student Evidence of Professional Growth

As discussed at times in this article, evidence of change is to be presented. While the program is still evolving and wrinkles are being ironed out, a number of strong encouraging artifacts have surfaced during the inception of such practices provoking this article. During this past year, the most promising professional growth of a PST is worthwhile presenting upfront. First, during the lesson enhancement project, this PST went above and beyond by developing a series of lessons to comprise a mini-unit. This was more than was asked for the assignment, but most encouraging is the fact that the lessons were dominated by student-centered lesson activities than teacher-centered direct instruction. The PST did not necessarily see teacher-centered direct instruction as *bad* or *poor*, the PST saw the engagement of students as the need for less direct instruction. Second, the same PST during methods and clinical experiences had an un-cooperating placement teacher. The classroom teacher had a full classroom set of TI-84 graphing calculators and never used them in class. The graphing calculators were actually still in the bubble wrap with no batteries and over a year old. However, during the final evaluated teaching lesson, the PST knew they needed to incorporate technology into the lesson. The PST was at a loss since the classroom teacher assigned the final teaching lesson to be the four mathematical operations for complex numbers. At first, the PST felt the calculator would just be a *checking tool*. However, after surfing the web and other online sources, the PST decided to allow the students to derive the rules for adding, subtracting, multiplying, and dividing complex numbers by using a lesson derived from the Texas Instruments website (see http://www.timath.com/algebra2/528 for newest version). Students computed answers but then had to conjecture the rules rather than just being told or shown examples. While the lesson had hiccups common for a PST, the most encouraging aspect occurred days later. This lesson was presented on a Friday. Later the next week, the PST conveyed conversations from their cooperating teacher and students to the faculty who observed and evaluated the lesson. The PST confessed the students from their class would not quit talking about the use of the graphing calculators to the point the cooperating teacher was a bit upset. However, the PST saw and recognized the potential of engaging students who might have otherwise been bored with replicating examples of arithmetic computation of complex numbers while actually discovering and learning mathematical properties with technology.

While that story is one of the most promising artifacts to share, others also are worth sharing. As previously promised, engagement and excitement has grown very evidentially for some PSTs in the technology course. During the very first class meeting of the technology course, PSTs write given five prompts for about 45 minutes. One statement reflects whether teaching mathematics with technology is essential or not. One PST specifically stated before the course instructor covered anything or spoke of NCTM in the course, “Technology is not essential for teaching mathematics. I learned it without any technology, so my future students should be able to as well.” Another PST claimed, “Using technology in a mathematics class should be for checking work or graphing of difficult functions.” It was apparent early that these two PSTs possessed a closed and firm view on using technology in the mathematics classroom. However, both of these PSTs changed their beliefs a lot after experiencing the technology course. Specifically, on the final course assignment (not for a grade as grades had already been finalized), the first PST changed their views dramatically. They stated, “Using the CBR motion detector to discover the real coefficients [–16, V_0, P_0] in the position function will be unforgettable. These numbers did not mean anything to me until the basketball activity. I see how technology can be used to teach math better.” The second PST attested to the radical functions lesson (appendix B) developing a stronger sense of how technology can be used to enhance understanding and not just for checking answers. They wrote,

> I always knew that solving radical equations required checking your answers for extraneous answers. I never knew why or the connections graphically. I never looked at radical equations from the other side. I mean, as the teacher, I have to make up good problems and this activity allowed me to use reversibility to create problems based on the graphs of functions rather than trying to create them all algebraically. It is so much easier now that I understand. I was never able to write a radical equation with two extraneous solutions without graphical aid. I now see how technology can advance understanding and is not just a crutch for getting answers. I guess my math teachers just didn’t know how to use technology like this class taught me.

While these examples are just a few of the emerging growth of a new generation of secondary mathematics teachers, one PST summed it up during a professional growth meeting. “Reading and reflecting on the math teacher articles from NCTM allowed me to see what great teachers are doing in the classroom since I rarely have seen these types of classrooms when I have been in local schools. I hope to be able to create and share advanced lessons myself some day!”

The professional growth meetings are held at the end of the class during final exam week. During these meetings with program faculty, PSTs get to talk about how they grew professionally during the course. The meetings are held throughout all three courses seen in figure 1 before student teaching. The meetings are a time for faculty and PSTs to have heart-to-heart conversations in a no-stakes professional environment. The meetings provide a real opportunity for faculty to understand what is going through the minds of the PSTs. The hope is graduating PSTs will see the professionalism of the faculty and remain in contact after graduation when provocative questions arise during their initial years of teaching. Program faculty also remain in contact with stellar graduating PSTs in the hopes they will recommend this program to perspective teachers when they choose a university program for a teacher education program.

Challenges and the Future

Program faculty realize the challenges that exist in having graduating pre-service teachers ready to be *best practice* teachers on day one. However, the philosophy of the coursework and tasks in these classes hopefully are setting a tone and giving PSTs a number of resources so they may fully implement some best practices during their first years of teaching. Getting more local cooperating teachers on board philosophically and to participate in professional development is still a challenge. Hence, headway can be made only at slow paces during PSTs' senior year unfortunately. However, early evidence appears headway is being made with some PSTs preconceived beliefs during their junior year and cooperating teachers have encouraged PSTs to "do their own thing" when teaching their own lessons. In the future, program faculty are planning to require [to assess professional teaching standards] best practice lessons during student teaching (internships) which is not currently a practice. Student teachers are evaluated by a local school teacher and/or a university faculty member for six lessons during student teaching. The requirement of best practice lessons being evaluated has only occurred during clinical placements concurrent with the methods course. The future plan is to have at least two of the six student teaching lessons requiring advanced teaching strategies and high-level cognitive tasks.

Summary

The changes to the secondary mathematics education course objectives is an attempt to challenge and reshape preconceived beliefs of pre-service teachers in a fairly traditional local school system and a state well below the national average in mathematics achievement. A strong commitment is underway with hopes that in three to five years, some graduates of the revamped TEP will become placement or cooperating teachers for future pre-service teachers in the program. Further, the program revitalization hopes to produce more teachers interested in participating in state mathematics endeavors, writing state test items, and revising or supporting advancing standards that involves more than skill and memorization tasks which we know from recent publications do not demonstrate college readiness (Cronin, Dahlin, Adkins, & Kingsbury, 2007; Fuller, Gesicki, Kang, & Wright, 2006). Cross-campus collaboration has also seen an advance in the mathematics coursework. The mathematics education faculty in the mathematics department will start (fall 2009) a two three-hour capstone course sequence using the textbook *Mathematics for High School Teachers: An Advanced Perspective* (Usiskin et al, 2003) for both courses. These courses typically will be taken simultaneously during the junior-year technology and curriculum courses. Constant collaboration and discussion has created an environment where little overlap exists within the mathematics and mathematics education coursework. PSTs get advanced cognitive task coursework from two sources simultaneously, mathematics and mathematics education. The capstone course development is based on the Conference Board of the Mathematical Sciences (CBMS) recommendation for secondary teacher education programs. Additionally, all pre-service teachers now conduct a standards-based student-centered inquiry lesson during one of the three observed and assessed lessons during the methods course clinical placement prior to student teaching. Like any teacher education program, quirks exist. However, cross-college collaboration and infusing challenging work into mathematics education coursework is showing signs that great things are on the edge of growing exponentially.

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Notes

[i] The secondary mathematics TEP focuses on both middle and high school grades. Secondary coursework focuses on both school levels. Clinical experiences occur in a wide variety of middle and high school classroom settings.

[ii] In the fall of 2009, the TI-Nspire CAS handhelds and computer software will become the exclusive tool used for all of these technology tools that can be used for teaching mathematics. The Ti-Nspire houses spreadsheets that can manipulate algebraic expressions, dynamic geometry package similar to Geometer's Sketchpad, a CAS, can be attached to CBR/CBL devices, and much much more. Pre-service teachers will all purchase a teacher pack of this handheld to be used in both their mathematics education courses and their two capstone mathematics courses.

[iii] Earlier in the curriculum course (not mentioned) and in the technology courses as a final project, PSTs have written a lesson plan using the TEP lesson plan template.

[iv] Flexibility, reversibility, and generalization are covered in the curriculum course at the beginning when discussing low and high-level cognitive tasks.

[v] University of Chicago School Mathematics Project (UCSMP), Core-Plus Mathematics Program (CPMP), and Interactive Mathematics Program (IMP).