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Keywords

Program evaluations, Mathematics teacher preparation, Pedagogical content knowledge, Mathematical knowledge for teaching, Middle grades mathematics pre-service teachers

USING A PEDAGOGICAL CONTENT KNOWLEDGE ASSESSMENT TO INFORM A MIDDLE GRADES MATHEMATICS TEACHER PREPARATION PROGRAM

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USING A PEDAGOGICAL CONTENT KNOWLEDGE ASSESSMENT TO INFORM A MIDDLE GRADES MATHEMATICS TEACHER PREPARATION PROGRAM

Introduction

In an effort to increase teachers' content knowledge, multiple curricula packages have been developed for standards-based mathematics instruction, which included instructional guidelines and strategies as recommended by the National Council of Teachers of Mathematics (NCTM) (Hiebert, 2003). Although these packages emphasized mathematical thinking and reasoning with problem solving skills and were meant to engage students by connecting with what they already know, mathematics teachers continued to have difficulty following the recommendations for teaching these curricula in their classrooms. Heaton (2000) and Latterell (2008) indicated that pre-service mathematics teachers had knowledge that allowed them to teach traditional mathematics, but their knowledge was not deep enough to teach mathematics consistent with *NCTM Standards.*

In light of the stated problems, many teacher education programs changed their curricula so that program coursework supported the NCTM documents; such programs took on the primary responsibility for guiding pre-service teachers in increasing the type of teacher knowledge that can actually bring sustainable impact on changing traditional classroom practices (Frykholm, 2005; Graham & Fennell, 2001). There is a growing recognition that more research is necessary to explore pre-service teachers' content knowledge in a pedagogical context and to identify topics in which pre-service teachers struggle with connecting content with pedagogy. In considering ways to inform and improve teacher preparation program effectiveness, research could provide valuable information on the current state of pre-service teachers' knowledge of mathematics and also could examine whether instruction is being provided at the appropriate certification level with ongoing systematic evaluation of teacher education programs. This study provides a springboard for future teacher preparation evaluation studies by taking a snapshot of grades 4-8 mathematics pre-service teacher knowledge by serving as a case study about using a teacher knowledge assessment to inform a middle grades mathematics teacher preparation program. It is noted that this study provides neither statistical inferential analysis nor generalized findings beyond the extent of the mathematics education component of the program at a large state university. The generalization and application of the results may require a setting similar to that of the study.

Literature Review

Mohr (2006) indicated that there exists a difference between the mathematics knowledge needed to be an effective teacher and that needed by a research mathematician. In fact, Heaton (2000) found that large number of mathematics teachers with quantitative skills had difficulty teaching with standards-based curricula when they lacked the knowledge of students' understandings and their typical misunderstandings. Ma (1999) reported that U.S. teachers were proficient at carrying out mathematical procedures but often could not come up with appropriate illustrations of mathematical concepts; that is, they could not explain to students why the procedures they prescribed worked, nor could they make connections to the related mathematical ideas. Additionally, it was found that elementary students struggled with making conceptual connections to mathematical ideas, and that such a difficulty could be attributed to the teacher's difficulty with conceptual understanding (Ball, Hill, & Bass, 2005).

Pedagogical Content Knowledge (PCK)

Studies show that effective teachers consider multiple ways of representing a mathematical problem and have the kind of special knowledge base consisting of integrated and related facts and rules, whereas novice teachers focus on solutions to a problem and on knowledge consisting of disconnected ideals, facts, and rules (Grossman, 1990; Zimmerlin & Nelson, 2000). Shulman (1987) coined the term PCK, which is specific content knowledge as applied to teaching, and further defined pedagogical content knowledge as the ability of the teacher to transform the content knowledge into a special kind of teacher knowledge that links content, students, and pedagogy.

Subject matter content knowledge is an understanding of the information and concepts within a particular domain, which includes a mastery of computational skills, procedures, and a conceptual understanding of mathematical truth in the discipline (Sherin, 2002; Shulman, 1987). PCK goes beyond only subject matter content knowledge to include presenting multiple representations of the ideas, analogies, illustrations, examples, explanations, thus, in essence, making the subject comprehensible to others (Shulman, 1987).

Mathematical Knowledge for Teaching (MKT)

Schoenfeld (2007) suggested that this type of PCK was different from traditional mathematics knowledge because mathematics knowledge does not consider anticipating student errors. Such capacity and knowledge may merit little attention for mathematicians. However, mathematics education researchers proposed such capacity and knowledge as the key dimensions of a construct called mathematical knowledge for teaching. Influenced by the notion of PCK, Ball and her colleagues developed the definition of mathematical knowledge for teaching (MKT) as a particular type of mathematical knowledge for carrying out the work of teaching mathematics (Ball, 1999; Hill, Rowan, & Ball, 2005).

Beyond the Scope of Traditional Mathematical Content Knowledge

Research implies that one of the more significant links between effective teaching and student achievement is that highly qualified teachers have more capacity and willingness to construct effective curricular materials for their students (Ball & Feiman-Nemser, 1988). Effective mathematics teachers do know mathematics well. However, Monk (1994) claimed that mathematics content knowledge is a necessary but not sufficient condition for effective mathematics teaching. Studies done by Graham and Fennell (2001), Taylor (2002), Sherin (2002), and Latterell (2008) support Monk's claim by adding that effective teachers enjoy doing mathematics themselves; think of their role as a teacher not so much as centrally directing learning and providing information, but as facilitating meaningful student exploration; believe that they can improve teaching by using feedback from students and colleagues; and, finally, believe that learning to teach mathematics is a lifelong process.

Indeed, the standards-based mathematics instruction results in greater student achievement gain when the standard-based curricula are taught by teachers who are knowledgeable, beyond the scope of traditional mathematical content knowledge, about students and pedagogical strategies (Darling-Hammond, 2006; Weiss et al., 2003). As a result, a new set of research was developed within the broader question of how pre-service mathematics teachers develop this new teacher knowledge that is different from traditional content knowledge and what experiences pre-service mathematics teachers should have in teacher education programs (Morris, Hiebert, & Spitzer, 2009; Taylor, 2002; Wilson & Ball, 1996).

The Use of a PCK or MKT Assessment

Hill, Schilling, and Ball (2004) asserted that there were no specific measures of teachers' pedagogical capacity in place in mathematics education, that measures of teachers' mathematical knowledge for teaching should be content specific, and that the measures should be specific to the teaching of an appropriate grade level. Hill, Rowan, and Ball (2005) pointed out that if the teacher's knowledge was not adequately measured, any following research might not make appropriate conclusions about the effect of teachers' knowledge on student learning.

Effectiveness in teaching resides not simply in the knowledge a teacher has accrued, but in how this knowledge is used in classrooms (Hill et al., 2005). With this in mind, assessing teachers through performance on tests of basic verbal or mathematics ability may overlook other key elements in quality teaching (Borko & Whitcomb, 2008). Based on the hypothesized domains of MKT (common content knowledge, specialized content knowledge, knowledge of content and students, and knowledge of contents and teaching), Hill, Rowan and Ball (2005) developed multiple-choice items on topics such as number, algebra, and geometry to measure elementary teachers' MKT. The test items were centered directly on the content of the K-6 curriculum rather than items on a middle school or high school exam. In models that used scores for first and third graders as the dependent variables, Ball and her colleagues succeeded in identifying a positive correlation between MKT and student achievement (Hill et al., 2005). This provides a theoretical framework supporting the use of a PCK or MKT assessment as a viable measure for evaluating teacher education programs. Ball and her colleagues found that, at the elementary level, a teacher's mathematical knowledge for teaching could predict math achievement and that the subjects' MKT was not related to their teaching or math ability (Hill et al., 2005; Hill, Schilling, & Ball, 2004). In this way, the measure developed by the Ball's study group (2005) produced the kind of quantitative data that served as empirical evidence to describe the impact of MKT on students' academic achievement. The field has extensive studies about teachers' mathematical knowledge for teaching with the focus on the elementary level. Recognizing the need to apply this at the middle school level, this study addresses middle grades pre-service teachers' pedagogical content knowledge and considers its implications.

Current Efforts to Improve Teacher Education Program Evaluations

Emerging research suggests that there is a paradigm shift in teacher education program evaluations from focusing on what or how things should be taught for per-service teachers, to thinking about what pre-service teachers are actually learning or what they express about the learning process (Darling-Hammond, 2003; Hall, Smith, & Nowinski, 2005). There are some reports regarding evaluation of teacher education programs using multiple strategies for evaluating the outcomes of teacher education. Cochran-Smith (2001) used multiple data sources for learning outcomes of teacher preparation programs, which include K−12 student achievement, candidates' scores on standardized teacher content knowledge tests, and documentation of performance assessments of teacher knowledge and skills during the various phases of the preparation program. Furthermore, Cochran-Smith (2001) argued that evidence alone in an evaluation does not necessarily inform teacher educators on how to further improve. She asserts that evidence needs to be interpreted. Furthermore, creating a culture of both evidence and inquiry in teacher education has the potential to build the capacity within teacher education programs to assess progress and effectiveness and gain knowledge to bring about a real change.

Research done by Latterell (2008), for example, offered a snapshot of ten pre-service teachers by conducting a survey instrument, interview, and two mathematics tests. Latterell (2008) called for more replication studies with a large group of pre-service teachers at various certification levels as well as with the pre-service teachers who actually learned mathematics with NCTM-oriented curricula when they were K-12 students.

Method

This is a case study that used a paper/pencil assessment called DTAMS to provide descriptions of knowledge of pre-service teachers seeking grades 4 – 8 mathematics certification in a large research university. Descriptive statistics was used to report content and pedagogical knowledge level of pre-service teachers. Included in the study are pre-service teachers (n = 29) who were enrolled in YEAR 1, YEAR 2, and YEAR 3 courses Fall 2010 – Spring 2011.

DTAMS

DTAMS are assessments for middle grade mathematics teachers that were developed at the Center for Research in Mathematics and Science Teacher Development (CRMSTD) at the University of Louisville. The assessments measure mathematics and mathematics pedagogy knowledge in four content areas (Number/Computation, Geometry/Measurement, Probability/Statistics, and Algebraic Ideas). The assessments were scored by CRMSTD staff, and a spreadsheet of scores by knowledge type (Type I – memorized/factual knowledge; Type II – conceptual understanding; Type III – reasoning/problem solving; Type IV – pedagogical content knowledge) for each teacher was provided. The questions posed in DTAMS were developed by mathematicians, mathematics educators, and teachers for the purpose of gathering information about the participant's PCK. CRMSTD announced on its website that internal reliability of DTAMS was determined by obtaining Cronbach's alpha and far exceeded the acceptable measure of 0.7 for internal consistency. Inter-scorer reliability was also established using percents of agreement among three graduate students who developed and used the scoring guides for scoring open-response items.

Research Site and the Program

The research site is an urban public research university located in a diverse metropolitan city of a southern US state. The teacher education program utilized in the study is a comprehensive teacher preparation program at the university that specifically prepares teachers for urban public school teaching.

The program has three main components (i.e., YEAR 1, YEAR 2, and YEAR 3): YEAR 1 focuses on introducing teaching as a career. Coursework and field experiences are designed to have teacher candidates interact with children in public schools and gain knowledge in the discipline area and general education theories. YEAR 2 focuses on skills and knowledge of teaching specific to the discipline. The pre-service teachers learn current methods for teaching and participate in practice teaching in school settings. YEAR 3, is the student teaching semester in which pre-service teachers gain experience in the work of teaching, partnered with classroom teachers in the hosting schools.

The middle grades mathematics teacher preparation coursework included nine courses for learning the content and pedagogy specific to teaching middle school mathematics. Coursework in YEAR 1 consisted of six mathematics courses and one mathematics education course. The mathematics courses provided a broad range of mathematical topics from algebra, probability, statistics, and problem solving to more advanced topics, such as number theory, analysis, and analytical geometry. The mathematics education course provided pedagogical preparations for teaching middle school mathematics. Coursework in YEAR 2 included two mathematics education courses in which pedagogical issues relating geometry and proportional reasoning were discussed.

Data Collection

The university's department of curriculum and instruction administered four tests, one for each content area (Number Computation, Geometry/Measurement, Probability/Statistics, and Algebraic Ideas), using the DTAMS in fall, 2010 and spring, 2011, as part of normal program evaluation efforts. Each assessment included 20 items that consisted of 10 multiple-choice and 10 open-response items. Although pre-service teachers were permitted to take as long as they needed, the average length of time to take the assessments was 75 minutes. Administration of the DTAMS followed the protocol provided by the developers of the instrument, including permitting the pre-service teachers to use graphing calculators. The assessments were scored by CRMSTD staff only. A spreadsheet of scores for each teacher was provided. The DTAMS Math Scoring Summary provided test results for all pre-service teachers, including aggregate scores and group averages grouped by the four assessments categories. For each assessment, the subcategories include knowledge type as well as the specific content areas (see Table 1).

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Table 1
Assessment Subcategories by Content Area

Number Computation	Probability and Statistics	Geometry and Measurement	Algebraic Ideas
▪ Whole Numbers ▪ Rational Numbers ▪ Integers ▪ Number Theory & Number Systems	▪ Statistics ▪ Probability	▪ Two-Dimensional Geometry ▪ Three-Dimensional Geometry ▪ Transformational Geometry ▪ Measurement	▪ Patterns, Functions, and Relations ▪ Expressions and Formulas ▪ Equations and Inequalities

Analysis of DTAMS Data

Data analyses focused on the results of DTAMS. Descriptive statistics, including tables of average scores, quartiles, and standard deviation, was used to represent the data of pre-service teachers' current professional knowledge on mathematics and its teaching.

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Results

Overall Performance

Pre-service teachers in YEAR 1 and YEAR 2 displayed the strongest knowledge in Number Computation, followed by Algebraic Ideas, Geometry/Measurement, and Probability/Statistics (see Table 2). However, the pre-service teachers' overall content knowledge was not strong with average scores lower than 60%. The two lowest-performing content knowledge areas were Geometry/Measurement and Probability/Statistics. Pre-service teachers in YEAR 1 performed better than YEAR 2 as a group.

Table 2
Average Group Scores of YEAR 1 and YEAR 2 Teachers by Content Area

	YEAR 1[a]	YEAR 2[b]
Content Area	Average Score	Average Score
Number Computation	57%	51%
Probability & Statistics	33%	25%
Geometry & Measurement	40%	34%
Algebraic Ideas	43%	40%

Note. [a]n = 11. [b]n = 18.

Pre-service teachers in both YEAR 1 and YEAR 2 displayed the highest scores for Memorized/Factual Knowledge, followed by Conceptual Understanding, Reasoning/Problem Solving, and Pedagogical Content Knowledge (see Table 3). Pre-service teachers have higher Memorized/Factual Knowledge than Pedagogical Content Knowledge.

Table 3
Average Group Scores of YEAR 1 and YEAR 2 Teachers by Knowledge Type

	YEAR 1[a]	YEAR 2[b]
Knowledge Type	Average Score	Average Score
Memorized & Factual Knowledge	57%	50%
Conceptual Understanding	51%	44%
Reasoning & Problem Solving	33%	30%
Pedagogical Content Knowledge	23%	25%

Note. [a]n = 11. [b]n = 18.

Performance by Content Areas

Number computation. Pre-service teachers have relatively higher Memorized/Factual Knowledge than Reasoning/Problem Solving or Pedagogical Content Knowledge in Number Computation. In addition, the larger standard deviation for pedagogical content knowledge scores exhibited by YEAR 1 pre-service teachers indicates a great amount of variability of pedagogical content knowledge. On the other hand, the smaller standard deviation for Memorized/Factual knowledge scores exhibited by the same group indicates less variability in the scores. For YEAR 2 pre-service teachers, the variability was the same for Memorized/Factual Knowledge and Pedagogical Content Knowledge.

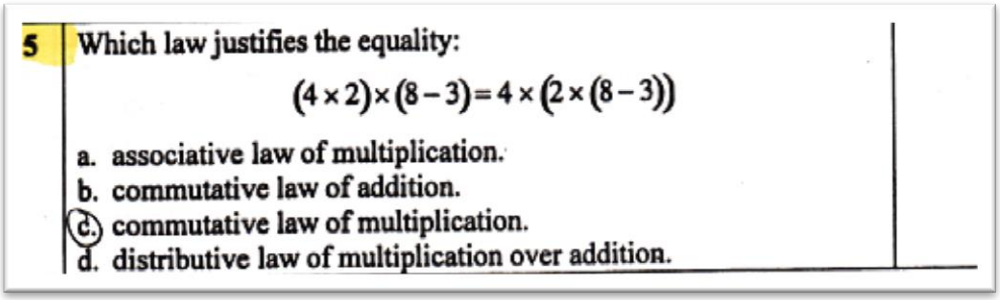
Probability and statistics. Almost every pre-service teacher in YEAR 2 had very low pedagogical content knowledge in Probability and Statistics, as indicated by a low average (8%) coupled with a low standard deviation (10). Moreover, YEAR 2 performed more poorly than YEAR 1 in Probability/Statistics. The pedagogical content knowledge for the YEAR 1 group is also very low. Pre-service teachers struggled with both Probability and Statistics at relatively the same rate.

Geometry and measurement. The YEAR 1 group displayed better content knowledge in Measurement than the other topics, and the YEAR 2 group displayed better content knowledge in Transformational Geometry than other topics.

Algebraic ideas. Pre-service teachers demonstrated better knowledge of Equations/Inequalities than other subcategories of Algebraic Ideas.

Student work in DTAMS. In order to illustrate how pre-service teachers typically answered DTAMS questions, one test per assessment was randomly chosen for analysis. Then, one question that had the lowest group score was selected. In Number Computation, for example, only six out of 18 pre-service teachers answered item 5 correctly (see Figure 1). The item assesses pre-service teachers' understanding of the three basic number properties that apply to arithmetic operations. Students typically memorize the rule in the following form, “ $(a \cdot b) \cdot c = a \cdot (b \cdot c)$ ”. In the test item, the equation looked different from the standard form, yet it was displaying the same rule because the substitution was done in the following way: $a = 4; b = 2; c = (8 - 3)$. When pre-service teachers do not have the opportunity to explore and analyze the number properties, they may struggle with this type of question.

Figure 1
Item 5 on Number Computation

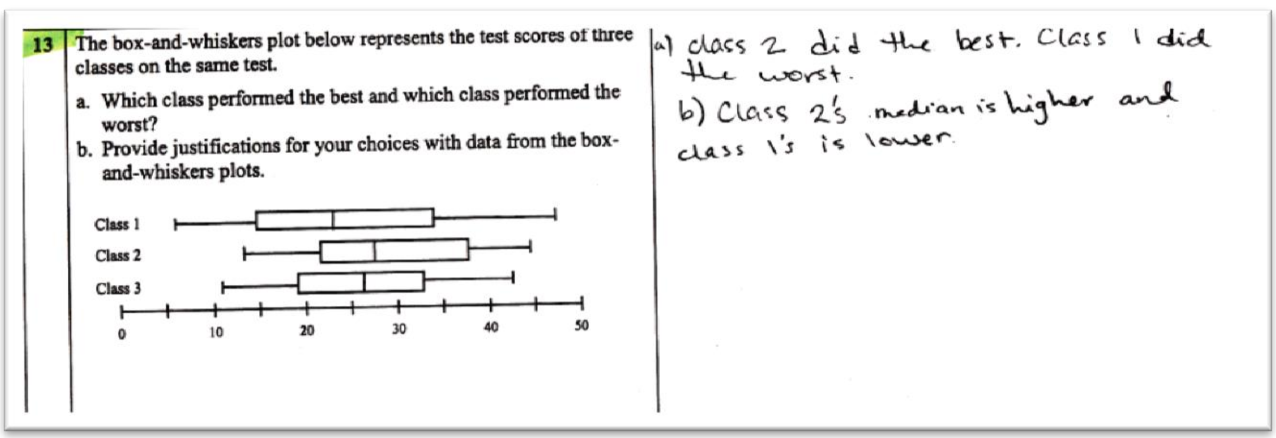

5 Which law justifies the equality:

$$(4 \times 2) \times (8-3) = 4 \times (2 \times (8-3))$$

a. associative law of multiplication.
b. commutative law of addition.
c. commutative law of multiplication.
d. distributive law of multiplication over addition.

In Probability/Statistics, only two pre-service teachers out of 18 answered item 13 correctly (see Figure 2). The item should reflect pre-service teachers’ understanding of visual representations of data, including the center, spread, and range of a distribution and conclusions about group differences. In the example below, the pre-service teacher response is incomplete since a definition of the best performance was not presented, and the response did not discuss the distribution’s spread, quartiles, or range.

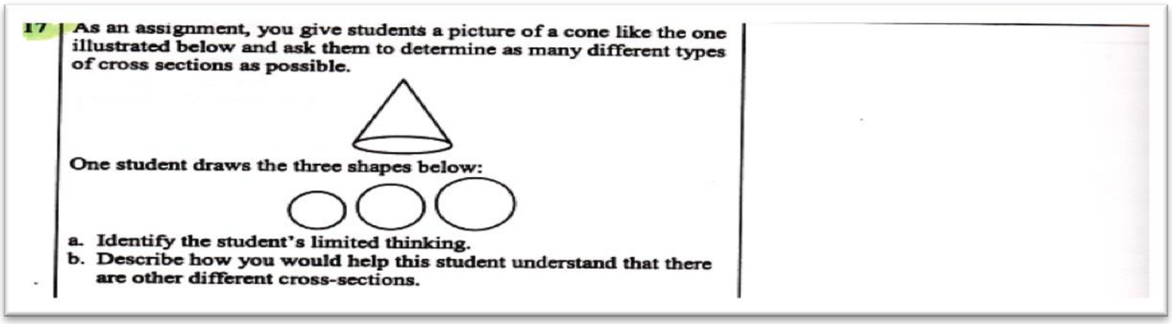
Figure 2
Item 13 on Probability/Statistics


13 The box-and-whiskers plot below represents the test scores of three classes on the same test.

a. Which class performed the best and which class performed the worst?
b. Provide justifications for your choices with data from the box-and-whiskers plots.

In Geometry/Measurement, only two pre-service teachers out of 18 answered item 17 correctly (see Figure 3). The item assesses pre-service teachers’ understanding of the relationship between 2-dimensional space and 3-dimensional space as well as their pedagogical capacity to identify student misunderstanding and to design appropriate learning activities addressing this gap. Most YEAR 1 pre-service teachers did not provide a response. Most YEAR 2 pre-service teachers attempted the question but had difficulty describing the students' thinking and creating other possible figures of the cross sections.

Figure 3
Item 17 on Geometry/Measurement

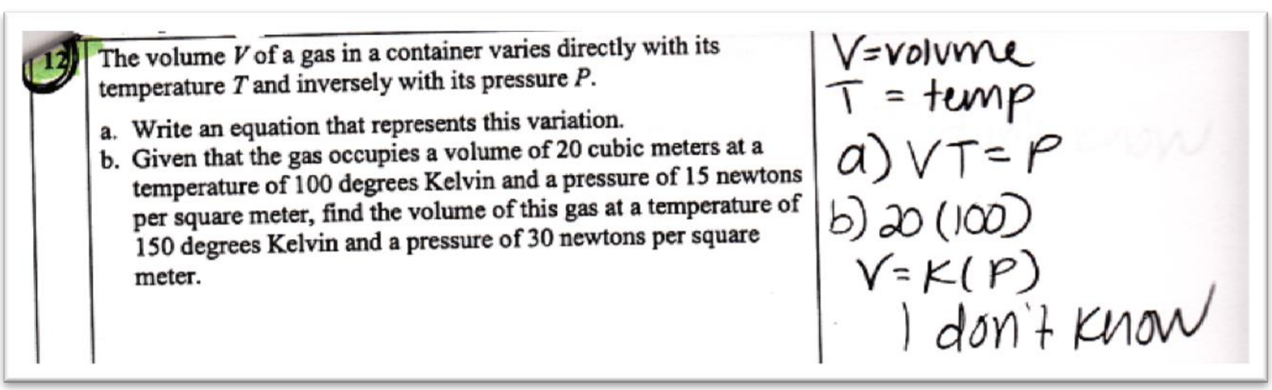

17 As an assignment, you give students a picture of a cone like the one illustrated below and ask them to determine as many different types of cross sections as possible.

One student draws the three shapes below:

a. Identify the student's limited thinking.
b. Describe how you would help this student understand that there are other different cross-sections.

In Algebraic Ideas, none of the pre-service teachers answered item number 12(b) correctly (see Figure 4). This item assessed pre-service teachers' understanding of direct and inverse proportionality. The correct answer to 12(a) is "$VP = kT$, where k is the constant of the variations." In the example below, the pre-service teacher provided an incorrect model and did not have the constant, *k*, in the model, which was used in the second part of the question. The second part of the question involves multiple steps in which the constant should be obtained from the known parameters and also involves applying the model to find the new volume with a different pressure. It is also noticeable that no units were mentioned in the discussion. This answer suggests that pre-service teachers struggle with constructing algebraic models for real-world settings and with using symbols and reasoning in analysis.

Figure 4
Item 12 on Algebraic Ideas


12 The volume *V* of a gas in a container varies directly with its temperature *T* and inversely with its pressure *P*.

a. Write an equation that represents this variation.
b. Given that the gas occupies a volume of 20 cubic meters at a temperature of 100 degrees Kelvin and a pressure of 15 newtons per square meter, find the volume of this gas at a temperature of 150 degrees Kelvin and a pressure of 30 newtons per square meter.

V=volume
T = temp
a) VT=P
b) 20 (100)
V=K(P)
I don't know

Discussion

A noticeable result was the overall low performance of pre-service teachers on the four assessments of both content and pedagogical content knowledge. The study considers possible reasons for this poor performance. First, the pre-service teachers might have not taken the testing

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seriously since they were explicitly told that the results were going to remain anonymous, which may have decreased motivation. Incomplete responses may indicate either a lack of effort on the part of pre-service teachers or a low level of persistence in problem solving. Second, the overall poor performance may reveal that the pre-service teachers simply did not have strong content knowledge. The incomplete answers could be the result of the levels of their content knowledge. Indeed, it is essential to recognize that pre-service teachers who completed the general mathematics courses still struggled with all four content areas of the DTAMS. This result calls for the mathematics faculty, the mathematics education faculty, and administrators from the respective university departments to collaborate with a renewed focus on course alignment and building a reliable assessment system for the mathematics courses for pre-service teachers.

Additionally, the examination of student answers provides a window into the current status of pre-service teachers' knowledge of mathematics and its teaching, supporting the conclusion that a lack of basic content knowledge has resulted in unsatisfactory performance on the DTAMS. This evidence raises concern that weak content knowledge could undermine the salient efforts of faculty members to educate effective mathematics teachers in areas such as curriculum design, children's thinking, communication of mathematical concepts, and persistence in problem solving. Schoenfeld (2007) claimed that solid content knowledge is a basis for strong pedagogical content knowledge. This study's results support his argument; pre-service teachers' pedagogical content knowledge scores were never higher than their content knowledge scores. Another interesting result is that most content knowledge scores in the four content area assessments across both YEAR 1 and YEAR 2 have higher standard deviations; this indicates the varying knowledge levels the pre-service teachers demonstrated.

The DTAMS results indicated that Probability/Statistics and Geometry/Measurement were the two major content areas in need of a change. Also, courses covering Number Theory or Problem Solving had not contributed much to increase the pre-service teachers' content knowledge. The clear pattern of giving up on a mathematics problem too easily in DTAMS points to a low level of persistence in problem solving. Responding to a need for coursework redesign, courses such as Introduction to Probability and Statistics, Formal and Informal Geometry, and Problem Solving in Mathematics can benefit from collaboration between departments with a shared commitment to school curriculum. This change might satisfy pre-service teachers' need for an exposure to pedagogy as well as learning mathematical ideas meaningfully and directly connected to the school curriculum.

Good school mathematics instruction involves a combination of mathematical knowledge and pedagogy. Mathematics teacher educators can provide valuable insights and information about what takes place in school classrooms. They have access to information on state curriculum guidelines and research studies on teachers' mathematical knowledge. For example, mathematics teacher educators can help validate college-level mathematical topics that might otherwise seem irrelevant to teaching by indicating how the understanding of advanced mathematics can help create useful examples or can devise appropriate illustrations in P-12 mathematics classroom. In return, mathematics faculty can keep mathematics education faculty informed of mathematical developments that have an impact on school mathematics. In this way, co-teaching can also serve as a concrete step to foster cooperation between these two groups. If co-teaching led to student success, it could spread to other mathematics courses in the program, and this collaboration could inform coursework redesigning.

Implications

This study calls for future research in two main directions. First, since the study is only a snapshot with limited data and participation, we recommend using DTAMS data with a larger number of participants and investigating pre-service teachers' completed coursework at the time of the study. More specific recommendations are as follows:

- Pre-service teachers should be motivated to participate in DTAMS testing.
- More pre-service teachers should participate in DTAMS testing. (With more test scores, for example, the study could have further explored why the YEAR 2 group performed more poorly than the YEAR 1 group on the DTAMS.)
- Research should collect the individual list of complete courses, perhaps through unofficial transcripts, and link this data to DTAMS scores.

More importantly, the second direction for future research is to continue the line of work that examines what experiences pre-service mathematics teachers need in order to improve their content knowledge as well as their pedagogical content knowledge. Future research may use the DTAMS results as a baseline to propose ways in which mathematics teacher educators develop activities designed to increase MKT. Researchers may start with exploring the mathematics methods courses and investigating the specifics on how the special knowledge for teaching mathematics is framed and implemented in the math methods courses. For instance, mathematics teacher educators need research that discovers the extent to which our pre-service teachers who graduated from a program with MKT-based curriculum are impacting students' learning.

In a similar vein, a recent study done by Kastberg, Sanchez, Edenfield, Tyminski, and Stump (2012) found that there was a recent emergence of methods course activities that focus on pre-service teachers' understanding of students' mathematical thinking. The researchers claimed that the methods course activities reflect new understandings of learning to teach (see Table 4) and that there exist few studies providing evidence of growth in the emergent frameworks in mathematics teacher preparation. Table 4 lists selected frameworks in conjunction with MKT deemed widely supported by mathematics teacher educators. Kastberg, Sanchez, and Tyminski (2013) called for a collective effort by mathematics teacher educators to propose methods activities in line with reformed mathematics teacher education and to share them in detail, allowing other mathematics teacher educators to implement and produce similar outcomes. The findings in this study echo the same effort in that the DTAMS data enabled mathematics teacher educators in the teacher preparation program of this study to think about reforming their curriculum and to develop relevant activities that help increase the level of MKT in both mathematics and mathematics education courses. In that context, the use of DTAMS assessment may serve as an instrument to produce empirical evidence on the impact of MKT-based practice.

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Table 4
Selected Framework Pertaining to MKT, adopted from Kastberg, Sanchez, Edenfield, Tyminski, & Stump (2012)

Select Frameworks
▪ Importance of knowing the learner
▪ Addressing the needs of all learners
▪ Task selection and analysis
▪ Understanding how students learn mathematics
▪ Emphasis on students' mathematics
▪ Cognitive or developmental stages and learning trajectories
▪ Motivation and engagement
▪ Modeling best practices for teaching
▪ Reflection on mathematics teaching and learning practice
▪ Integration of content and pedagogy/mathematical knowledge for teaching

Closing Remarks

Assuming that low content knowledge is a pervasive pattern found in the candidates of middle grades mathematics teacher preparation programs, we believe it is important to recognize that it is difficult for mathematics education faculty to build pedagogical prowess upon low knowledge in mathematical content. Equally important is to consider that solutions to increase mathematics knowledge may lie in how and what mathematics is actually taught, not only in the P-12 classrooms but also in the college mathematics courses. In order for teachers to implement the standards-based curriculum, they must have opportunities in their college courses to learn mathematics with a set of process standards similar to those they are expected to teach in a P-12 classroom that is in step with the emerging school curriculum.

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