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Examining Mathematics Teacher Content Knowledge Using Policy, State Certification Tests and Transcripts

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This study examined mathematics teacher content knowledge in terms of policy maker recommendations, college coursework and teacher certification mathematics test scores. Transcript analysis indicated poor alignment of national policy maker recommendations for mathematics teachers and college degrees in mathematics. Teacher certification test results based on mathematics coursework preparation suggested that state educator standards require knowledge of content taught in middle school, high school, and in introductory college mathematics courses. Policy makers are asked to consider the validity of content tests, which align poorly with college degrees in mathematics and are used as primary gatekeepers to teacher certification.

Introduction: What Content Knowledge High School Mathematics Teachers Should Know

For over two decades, content knowledge, as evidenced using college transcript information *and* content knowledge as demonstrated using scores on state teacher exams, have been used as criteria to screen candidates seeking secondary undergraduate teacher certification in Texas (Texas Higher Education Coordinating Board, 2007; State Board for Educator Certification, 2009). However, the landscape of teacher preparation has experienced rapid evolution. Since 2000, increasing numbers of new Texas teachers complete teacher certification *after* receiving a degree via alternative certification programs (ACPs), and many of the ACPs are commercial enterprises operating outside of colleges and universities (State Board for Educator Certification, 2009).

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Alternative certification candidates may be admitted to secondary teacher education programs based on a passing score on a state content exam *or* demonstrating completion of at least 12 semester credit hours of content coursework related to a certification field. The 12 hour, minimum content requirement raises important questions about a system of disparate certification requirements which hold undergraduates and graduates to different content standards. For this reason, our investigation examined the relationship between college coursework in mathematics and the grades 8-12 Mathematics Texas Examination of Educators Standards (TExES). Specifically, this study explored the relationship between mathematics coursework and the state mathematics exam using the variables, semester credit hours and the grades 8-12 TExES Domain scores for mathematics (i.e., number and operations; patterns and algebra; geometry and measurement; probability and statistics; mathematical processes and perspectives; and mathematical learning, instruction, and assessment).

Teacher Content Knowledge According to Texas Politicians

Texas Certification requirements for undergraduates who seek initial teacher certification must be approved through the Texas Higher Education Coordinating Board (THECB) and the State Board for Educator Certification (SBEC). Presently, alternative certification requirements for a secondary teaching field include:

1. Completion of a bachelor's degree in a content field that is closely aligned with the certification field sought;
2. Pedagogy coursework; and
3. Passing scores on state content and pedagogy teacher examinations.

In Texas, undergraduate education degrees have not been awarded for over 20 years. Instead, undergraduates pursuing secondary teacher certification must complete a degree with a content major accompanied by no more than 24 hours of pedagogy coursework (THECB, 2007). Programs which utilize a professional development school (PDS) model are authorized a maximum of 24 hours of pedagogy coursework while all other programs are capped at 18 hours of pedagogy. However, the content knowledge required of *graduates* who pursue alternative teacher certification varies considerably compared to undergraduate teacher certification requirements, which are tied to the degree approval process of the THECB. Additionally, all teachers must pass state content examinations, as the content knowledge of teachers has been a concern for many years since teacher testing in Texas was first implemented during March 1986 (Texas Administrative Code Rule §230.5 d).

Recently, the Texas State Board for Teacher Certification amended the criteria utilized for admission of graduates to Texas teacher preparation programs. One of these changes addressed content preparation for secondary teachers. Texas Administrative Code Rule §227.10 (3) (C) requires:

> a minimum of 12 semester credit hours in the subject-specific content area for the certification sought, a passing score on a content certification examination, or a passing score on a content examination administered by a vendor on the Texas Education Agency (TEA)-approved vendor list published by the commissioner of education for the calendar year during which the candidate seeks admission.

This rule change reveals much disparity with regard to formal content preparation of undergraduates and graduates. For example, a graduate teacher certification candidate may hold a degree in psychology and the candidate's transcript may demonstrate *any* 12 hours of mathematics coursework which might be lower-level coursework (e.g., college algebra, precalculus, business calculus, elementary probability and statistics). A comparison of minimum *graduate* teacher certification requirements to *undergraduate* degree requirements at the University of North Texas reveal just how much disparity exists on a comparative basis. An undergraduate teacher candidate pursuing a BA in Mathematics will complete a minimum of 34 prescribed student credit hours (SCH) of mathematics and a teacher candidate pursuing a BS in Mathematics will complete a minimum of 40 prescribed SCH of mathematics (UNT, 2009). Thus, the content coursework for an undergraduate teacher candidate may require more than three times the coursework of a graduate of only 12 hours of mathematics course work. This legislative change continues a long standing discussion about the importance of teacher content knowledge and critical variables which may be used to gauge the quality of content knowledge.

Teacher Content Knowledge According to National Policymakers

There has been a long standing lack of consensus about the mathematics knowledge that is required for teaching. In an attempt to quantify teacher content knowledge, a number of policymakers have issued documents which address the content knowledge needed in order to become an effective teacher (Conference Board of the Mathematical Science, 2001; National Council of Teacher of Mathematics, 1991; National Commission on Teaching & America's Future, 1996; American Council on Education, 1999). In an effort to bring standards to the process, these documents employ a logical process in which experts identify topics, courses, and knowledge believed to be requisite to mathematics teacher training.

One such policy making organization is the National Council of Teachers of Mathematics (NCTM) which organizes program standards for the initial preparation of mathematics teachers around four broad topics of teacher knowledge and skills: Process, pedagogy, content, field experience. The topics are divided into sixteen standards which are further subdivided into 82 indicators for what mathematics teachers should know and be able to do (NCTM, 2003). Standards 9-15 address understanding specific concepts and procedures as well as the process of doing mathematics. The seven content standards for initial preparation of mathematics teachers are illustrated in Table 1. A more comprehensive review of the standards is available in *Principles and Standards for School Mathematics* (2000).

Table 1. NCTM Content Standards for Initial Preparation of Mathematics Teachers

Standard No.	***Description***
Standard 9	Knowledge of Number and Operation
Standard 10	Knowledge of Different Perspectives on Algebra
Standard 11	Knowledge of Geometries
Standard 12	Knowledge of Calculus
Standard 13	Knowledge of Discrete Mathematics
Standard 14	Knowledge of Data Analysis, Statistics, and Probability
Standard 15	Knowledge of Measurement

With regard to college coursework, NCTM states, “It is expected that teachers of mathematics in grades 9-12 will have the equivalent of a major in mathematics to gain sufficient understanding of the recommended mathematics. The coursework for teachers at this level assumes as prerequisite four years of mathematics for college-intending students or an equivalent preparation (NCTM, 2000, p. 134).”

During 2001, The Conference Board for the Mathematical Sciences (CBMS) provided a similar view about the content knowledge needed to teach high school mathematics (CBMS, 2001). Five content topics were described including algebra and number theory; geometry and trigonometry; functions and analysis; data analysis, statistics, and probability; and discrete mathematics and computer science. Additionally, an outline of mathematics and supporting courses to provide core knowledge for high school mathematics teachers was proposed (Table 2).

Table 2. CBMS Outline of Mathematics Courses Recommended to Provide Core Knowledge for High School Mathematics Teachers

Year	***College Mathematics Courses***	***No. Courses***
Year 1	Calculus, introduction to statistics	3-4
Year 2	Linear algebra	1
Year 3	Abstract algebra, geometry, discrete mathematics, and statistics	4
Year 4	Introduction to real analysis, capstone	2
Total	All topics	10-11

Other national policy organizations such as The National Commission on Teaching and America's Future (1996), Interstate New Teacher Assessment and Support Consortium (1993), and the National Board for Professional Teaching Standards (1991) echo the position of NCTM and CBMS; teacher preparation must impart a deep understanding of content. "High quality teaching requires that teachers have a deep knowledge of subject matter. For this there is no substitute" (The Glenn Commission National Commission on Mathematics and Science Teaching for the 21st Century, 2000).

Teacher Content Knowledge According to Researchers

A different lens for viewing teacher knowledge focuses on teacher variables such as coursework taken, grade point average, type of degree, and state certification. A number of researchers have demonstrated students taught by teachers with a major or minor in mathematics score higher on tests compared to students of teachers without a major or minor in mathematics (Aaronson et. al. 2003; Goldhaber and Brewer, 1997; Goldhaber and Brewer 2000; Betts, 2003; Cavalluzo, 2004, Monk, 1994; Wenglinski, 2000, 2002; Darling-Hammond, 1999).

Goldhaber and Brewer (1997) used data from the National Educational Longitudinal Studies of 1988 (NELS) and found that teachers who hold a degree in mathematics or mathematics education have statistically significant positive effects on student test scores. Similar findings were demonstrated in Linda Darling-Hammond's (1999) research about student achievement in reading and mathematics. She found, "The strongest, consistently negative predictors of student achievement, also significant in almost all cases, are the proportions of new teachers who are uncertified (r between -.40 and -.63, $p<.05$) and the proportions of teachers who hold less than a minor in the field they teach (r between -.33 and -.56, $p<.05$)."

Using scores from students' who scored similarly on a pretest, Monk (1994) determined a positive relationship between secondary students' performance on mathematics post-tests derived from the National Assessment of Educational Progress and the number of mathematics courses taken in college. He found that this relationship weakened after completing five courses in mathematics. Similar results were described by Begle (1979) who found that once a teacher reached a certain level of coursework, there was no relationship between students' mathematics performance and the number of college mathematics courses their teachers had taken or the associated teachers' average grade for the courses.

Betts, Zau, and Rice (2003) were some of the first researchers to study the relationship between high school mathematics teacher content preparation and student achievement. Using the Iowa Test of Basic Skills and the Test of Achievement and Proficiency Scores to measure high school mathematics achievement, they found that:

> In terms of their students' academic performance, teachers with higher GPAs start out their careers at an advantage over their low-performing peers, but the effect is not constant over time. Specifically, college performance and real-world teaching experience interact, reducing the gap in their teaching effectiveness. The positive effects of math content hours grow each successive year the teacher is in the classroom. All else equal, a teacher who took 11 h of math content will have higher student math scores than a teacher who took 10 h of math content and will have incrementally higher student math scores over the years.

Harris and Sass (2007) conducted a study of Florida mathematics teachers in grades 3-10. Their results show increases in the number of subject content credits completed by a teacher was positively correlated with the performance of high school math students. Similar results for mathematics were reported by Betts and colleagues (2003) regarding the effect of teachers holding a major or minor in mathematics on for middle school, but not high school student achievement. In a study of eighth grade mathematics students, Wenglinski (2002) found a 39% increase in grade for mathematics students taught by a teacher holding a major or minor in mathematics, and NAEP mathematics scores were positively associated with a major in mathematics (2002).

Using data from 108,000 students in Miami Dade Schools, Cavalluzo (2004) examined the association between teacher quality indicators and student achievement in mathematics in the ninth and tenth grades. Results indicate the type of mathematics teaching certification, job assignment, advanced degrees and National Board Certification were statistically significant predictors of student math achievement.

Although it is not the focus of this study, it has not escaped our attention that a more powerful type knowledge connects teacher content knowledge with knowledge about *how* students learn a particular concept. This knowledge is referred to as pedagogical content knowledge (PCK) and emphasizes how information is best packaged to overcome learning difficulties. Various researchers (Carpenter, Fennema, Peterson, & Carey, 1988; Carpenter, Fennema, Peterson, Chiang, & Loef, 1989; Franke, Carpenter, Fennema, Ansell, & Behrend, 1998) have established strong links between student achievement for whole number arithmetic using cognitive guided instruction. Research suggests that completing pedagogical content knowledge coursework is a much more powerful way to increase student achievement than completing content coursework alone (Barnett & Hodson, 2001; Frykholm & Glasson, 2005; Kinach, 2002; Monk, 1994; Nakiboglu & Karakoc, 2005; Shulman, 1986; Veal & Kubasko, 2003).

Teacher Testing as an Indicator of Content Knowledge

Even though use of teacher testing is widespread, and more than 600 tests are used across the United States to measure a teacher candidate's basic skills or content knowledge, Cochran-Smith and Zeichner (2005) suggest there is little evidence teacher tests are an effective tool for predicting who will be an effective teacher. Given the rapidly changing landscape of teacher certification brought on through alternative certification, lowered retention rates, and multiple perspectives held by various stakeholders. This is an area where much research is warranted. There remains a good deal of uncertainty about the value of testing to screen out low quality teachers or the use of teacher testing as a tool to judge teacher quality. Research focused on teaching secondary mathematics teachers is thin and almost nonexistent.

Recently, a few researchers have examined the link between teacher quality variables and/or student achievement. Goldhaber (2007) examined the relationship between teacher tests and student learning gains as measured using a value added system tied to the North Carolina Course of Study. His analysis included 24,237 Grades 4-6 teachers in self-contained classrooms with either a NTE and/or Praxis test score and 722,166 students. Statistically significant effects were noted between teacher tests scores and mathematics achievement. Goldhaber (2007) also explored the use of Praxis II mathematics tests as a screening device and found teachers who met the North Carolina standard to be more effective in math (about 6% of a SD) compared to teachers who did not meet the standard. Another study conducted in North Carolina found teacher licensure test scores had significant positive effects on students' 5th grade math scores (Clotfelter, Ladd, and Vigdor, 2006).

Using data from the Schools and Staffing Survey, Angrist and Guryan (2007) investigated teacher quality for 160 teachers and 3000 students. Their analysis employed various demographic variables including test scores (i.e., general and subject specific), teacher demographics, and teacher wage and quality measures (e.g., type degree awarded, average SAT, type university attended, majored in teaching subject). They concluded there was no significant impact of testing on teacher quality, although teacher testing requirements were associated with higher teacher wages, and testing was negatively associated with Hispanic representation in the new teacher pool.

In an examination of mathematics teachers enrolled in a Texas graduate teacher certification program, Harrell (2009) examined the relationship between Grades 8-12 mathematics teacher content preparation and teacher test scores on the Grades 8-12 Mathematics TExES. A fail rate for 2/5 of candidates was found although transcript analysis showed strong content preparation with accompanying high grade point averages for teacher candidates. Of the variables examined, only grade point average for mathematics coursework was a statistically significant predictor for passing the mathematics TExES.

A second Texas study conducted by Hanushek et. al. (2005) reported student achievement in grades 4-8 mathematics as measured by the Texas Assessment of Academic Skills was unrelated to teacher certification test scores. However, they did not distinguish the type of certification (e.g., K-8 Elementary, 4-8 mathematics, 8-12 mathematics) nor did they use available scaled test scores, but rather used pass/fail data for their analysis.

Russell (2005) marks the 1970s as the beginning of the trend toward formalized teacher testing in the United States. In an effort to promote high standards in the teaching profession and guarantee a minimum level of competency in the classroom, states in the 1980s and 1990s began to adopt various strategies including teacher testing as a means of ensuring that only qualified, competent individuals entered the classroom. Teacher testing presented itself to policy makers as an efficient, cost-effective way to accomplish this goal. Given a lack of research linking teacher content knowledge as expressed using transcripts to teacher content tests, this study seeks to examine the relationship of college coursework in mathematics and the 8-12 TExES Mathematics Domain scores (i.e., number and operations; patterns and algebra; geometry and measurement; probability and statistics; mathematical processes and perspectives; and mathematical learning, instruction, and assessment).

Rationale and Research Question

Recent changes in Texas state content requirements for admission to teacher preparation reduced the number of semester credit hours required to begin a teacher preparation program from twenty four hours (including 12 upper-level hours) to twelve semester credit hours of mathematics coursework. For this reason, the purpose of this study was to examine the relationship between mathematics semester credit hours recorded on college transcripts and the grades 8-12 TExES Domain scores for mathematics (i.e., number and operations; patterns and algebra; geometry and measurement; probability and statistics; mathematical processes and perspectives; and mathematical learning, instruction, and assessment). The grades 8-12 TExES Mathematics certification examination is purported to specifically align with Texas education frameworks. The test frameworks can be viewed on the Texas State Board for Educator Certification website (State Board for Educator Certification, 2009).

The following research questions were used to assess the subject area knowledge of 8-12 mathematics teachers:(1) What is the relationship between the number of mathematics semester credit hours completed and the grades 8-12 Mathematics TExES Domain scores? and (2) How do college transcripts align with state and national policy maker recommendations?

Method

Participants

Data was collected from 30 mathematics students who were enrolled in the Alternative Certification Program during the period, 2004 through 2009. All students hold an undergraduate degree and meet minimum program GPA admission requirements (2.8 overall undergraduate GPA where 4.0 = A or 3.0 on the last 60 hours of undergraduate coursework) and meet minimum requirements for standardized test scores (Teacher Certification, 2009).

According to State Board for Educator Certification records, 18 participants were female and 12 were male. Ethnicities represented in this study include four African American, two Asian, 22 Caucasian, and two students who did not report ethnicity. Nineteen students held degrees from Texas universities (4 were

UNT graduates) and 11 students completed degrees outside of Texas.

Research Design

Descriptive data and correlation analyses were used to draw conclusions about the subject area knowledge of the individuals in the sample and to assess the significance of the completing a minor or major in mathematics. Descriptive data include the mean, median, mode, pass/fail information, and standard deviations for variables related to the study. Correlations were used to investigate the strength of the relationship among course work associated grades 8-12 Mathematics TExES Domains.

The undergraduate mathematics courses were categorized into the seven National Council of Teachers of Mathematics content standards (see Table 1). This was accomplished by aligning the course descriptions to the indicators within each mathematics standard (NCTM, 2003). The Conference Board of Mathematical Sciences (CBMS) identified five major mathematical strands: 1) Algebra and Number Theory, 2) Geometry and Trigonometry, 3) Functions and Analysis, 4) Statistics and Probability, and 5) Discrete Mathematics. For each strand CBMS identified corresponding courses for teachers of mathematics (Table 2). Therefore a course was categorized based on the emphasis within the NCTM content standard and corresponding CBMS mathematical strands. The NCTM measurement content standard was excluded as there was no comparable CBMS mathematical strand.

Results

Thirty students completed the grades 8-12 Mathematics TExES. Descriptive statistics for TExES Domain Scores are shown in Table 3. Mean scores range from 245.37 to 267.30 with standard deviations between 27.34 and 40.067. The most score variability was found in Domain VI (Mathematics Pedagogy). Fifteen students failed at least one domain of the test and thirteen students failed more than one domain of the 8-12 TExES Mathematics examination (Table 3).

Table 3. Descriptive Statistics for 8-12 TExES Mathematics Domains I-VI[a]

Product	***Domain I***	***Domain II***	***Domain III***	***Domain IV***	***Domain V***	***Domain VI***
N	30	30	30	30	30	30
Mean	267.30	262.00	255.80	245.37	249.93	253.23
Median	276.50	268.00	261.50	247.50	266.00	264.00
Mode	280.00	252.00[b]	242.00	240.00	273.00	300.00
Std. Dev.	27.35	25.51	27.96	30.86	34.35	40.07
Range	96.00	107.00	135.00	130.00	128.00	152.00
Min.	204.00	193.00	165.00	170.00	172.00	148.00
Max.	300.00	300.00	300.00	300.00	300.00	300.00
No. Failing Scores	5	4	4	8	7	8

[a]240 Is a Passing Score; [b]Multiple modes exist. The smallest value is shown.

The individual test domain scores for each candidate and the pass and fail rates are shown in Table 3. One fourth of the individuals taking the 8-12 Mathematics TExES failed the state exam on the initial test attempt. Program admission and Texas minimum requirements for content area coursework for the participants included a minimum of 24 hours of content area coursework in the target certification field with at least twelve of the 24 hours taken at the junior, senior, or graduate level.

The total number of undergraduate semester credit hours for mathematics is shown in Table 4. The mean number of mathematics semester credit hours is reported for seven categories which are aligned with the National Council for Teaching Mathematics and CBMS recommendations (i.e., number and operations, algebra, geometry, calculus, discrete mathematics, data analysis, statistics & probability, and other mathematics content coursework).

Table 4. Descriptive Statistics for Mathematics SCH by Category

Product	***NO***[a]	***Algebra***	***Geometry***	***Calculus***	***Discrete***	***Probability***	***Other***
N	9	27	7	28	9	23	17
Missing	21	3	23	2	21	7	13
Mean	3.44	7.00	5.43	14.46	3.67	6.87	6.00
Median	3.00	6.00	6.00	15.00	3.00	6.00	6.00
Mode	3.00	3.00	3.00	15.00[b]	3.00	3.00	6.00
Std. Dev.	1.01	4.66	2.51	4.63	1.32	3.70	3.06
Range	3.00	15.00	6.00	25.00	3.00	11.00	9.00
Min.	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Max.	6.00	18.00	9.00	28.00	6.00	14.00	12.00
Sum SCH	31.00	189.00	38.00	405.00	33.00	158.00	102.00

[a]NO = Number operations and Other = other mathematics courses not categorized in the table; [b]Multiple modes exist. The smallest value is shown.

As shown in Table 4, a number of missing values are reported as student degree requirements were inconsistent with regard to the CBMS and NCMT recommendations (i.e., number and operations, geometry, and discrete mathematics). Mean mathematics semester credit hours ranged from 3.44 (Number and Operations) to 14.46 (Calculus) with standard deviations from 1.01 to 4.66. Reported medians are highly similar to mean scores and ranged from 3.00 (Number and Operations) to 15.00 (Calculus). The most common categories for coursework included Calculus and Algebra (specifically linear algebra). The sum total semester credit hours for all categories ranged from 31 to 405 SCH. The sum total semester credit hours for recorded for Calculus was 405 and the sum total semester credit hours for Algebra was 189.

The relationship between the 8-12 TExES Domain scores for Mathematics and semester credit hours for each domain is shown in Table 5. Three statistically significant correlations between domain scores and Algebra SCH were found for 27 students. Domain II and Algebra were statistically significant and negatively correlated (P = -.456). Domain III and Algebra were statistically significant and negatively correlated (P = -.442). Domain VI and algebra were statistically significant and negatively correlated (P = -.421). Domain III and Discrete Mathematics were statistically significant and negatively correlated (P = -.674) but the number of candidates was small (n = 7). That is, TExES scores for Domains II, III, and VI increased as mathematics coursework decreased.

Discussion

Disparate Undergraduate and Graduate Requirements for Mathematics Teachers

The *No Child Left Behind* legislation definition for teacher quality, has dramatically changed the landscape of teacher preparation in Texas. No longer is teacher preparation the domain of higher education; instead private alternative certification programs dominate the landscape training about 6/10 new Texas teachers. The teaching field of mathematics continues to be an area of great teacher need, both in the Metroplex and statewide. Texas is currently recruiting about half the mathematics teachers needed to fill school vacancies (Fuller, 2009). In 2008, filling mathematics teaching positions became even more challenging due to a sweeping school reform package which requires Texas freshmen to complete four mathematics courses in order to meet state recommended high school graduation requirements (Texas Education Code, 2007).

The move toward private alternative certification providers has corresponded with an increased reliance on state testing as the sole measure of teacher knowledge accompanied by sharp declines in formal content preparation for teacher candidates who already hold any degree and are seeking teacher certification. This disparate content preparation is most apparent with regard to undergraduate teacher certification programs in Texas universities which are required by law to include a content major (~ 30-42 SCH) in their field. Thus, the content preparation requirement for undergraduates and graduates is more often than not inequitable.

Table 5. Correlations for 8-12 TExES Mathematics Domains I-VI and Six Categories of Mathematics SCH

	D1	*D2*	*D3*	*D4*	*D5*	*D6*	*N&O*	*Alg*	*Geo*	*Cal*	*Disc*	*P&S*	*Other*
D1	1												
D2	**.507**	1											
D3	**.522**	**.473**	1										
D4	.166	**.463**	.329	1									
D5	.093	.319	**.428**	**.367**	1								
D6	.053	**.482**	.261	.253	.349	1							
N&O	-.107	-.616	-.169	-.251	-.564	.323	1						
Alg	-.347	**-.456**	**-.442**	-.109	.138	**-.421**	.312	1					
Geo	.337	.221	-.377	-.047	.101	.114	a	.120	1				
Cal	-.307	-.175	-.123	-.127	-.060	.081	.003	-.137	-.169	1			
Disc	-.415	-.114	**-.674**	-.208	-.228	-.101	A	.256	.500	.439	1		
P/S	-.039	-.99	-.022	-.060	-.275	-.197	.283	.268	-.418	.062	.000	1	
Other	-.169	-.080	-.250	.399	.075	.245	.593	**.741**	.417	-.306	-.400	.416	1

Alg = Algebra; Geo = Geometry; Cal = Calculus; Disc = discrete mathematics; P/S = Probability and Statistics; Other = Other mathematics courses Correlations for the .05 level are shown in bold. The .01 level is shown in non-italic bold type.

Since there is already a severe teacher shortage in mathematics, the points above raise important questions about conflicting legislation which promotes content shortcuts for graduates while other legislation requires undergraduates to complete a content major. What is the impact of increasing numbers of students graduating then completing an alternative certification program? Is it desirable for secondary school teachers to complete interdisciplinary degrees instead of content degrees? It would seem these practices only increase the time and money it takes to become a certified teacher while reducing the content knowledge of secondary teachers.

Missing Knowledge: Geometry and Discrete Mathematics

An interesting finding is the absence of specific coursework in geometry and discrete mathematics found during the transcript analysis. NCTM recommends the study of geometry (Standard 11) and the study of Discrete Mathematics (Standard 13) as does the CBMS (3^{rd} year coursework). As shown in Table 4, twenty-three candidates were missing specific coursework in geometry and twenty-one candidates did not take a course in Discrete Mathematics.

CBMS (2001) recognizes the contribution of mathematics courses such as calculus and linear algebra in experiences related to "important geometric ideas and techniques". For this reason, CBMS recommends that secondary mathematics teachers have at least one course in college geometry to strengthen their geometric understandings.

CBMS (2001) also recommends that secondary mathematics teachers take at least one course in discrete mathematics and one course in computer science. The rationale for including these courses is to construct meaning for secondary school students through the application of discrete mathematics (e.g., robotics, cryptography, software development) and to encourage career explorations of fields such as computer science, operations research, and economics.

Disparate State and National Coursework Standards for TX Mathematics Teachers

Recommendations of CBMS, NCTM, the National Commission on Teaching and America's Future (1996), Interstate New Teacher Assessment and Support Consortium (1993), and the National Board for Professional Teaching Standards (1991) agree, teacher preparation must impart a deep understanding of content. This brings into question the wisdom of relying on a state content examination, particularly a content examination not well aligned with university mathematics degree requirements, as the sole measure of teacher knowledge. Like reading, learning mathematics is a sequential and cumulative process. Mathematics experts have knowledge and familiarity with the scope and sequence for learning mathematics. Based on the assumption that three SCH is equivalent to one course, results of this study indicate the average candidate completed about one course in number and operations , three courses in algebra, two in geometry, five in calculus, one in discrete mathematics, two in statistics, and two other mathematics courses (~30 SCH).

The Relationship between TExES Domains and Content Coursework

However, the relationship of mathematics coursework with the relevant 8-12 Mathematics TExES Domains indicates there is no relationship between mathematics coursework or the relationship is negative. With respect to the relationship between 8-12 Mathematics TExES Domain II (Algebra) and algebra coursework in terms of SCH derived from candidate transcripts, the highest scores in Domain two are associated with six or less SCH. That is, a candidate who took only one or two courses in Algebra scored higher than candidates who took four or more algebra courses. Furthermore, Linear Algebra was the course most often taken by twelve of fifteen students who completed only one or two courses in Algebra. Overall, this suggests a negative association between mathematics coursework and TExES Domain II scores and that the most important course associated with passing TExES Domain II is Linear Algebra.

With respect to the relationship between 8-12 Mathematics TExES Domain III (Geometry) and algebra coursework in terms of SCH derived from candidate transcripts, the highest scores in Domain III are associated with three to six SCH which mirrors the results for Domain II and Algebra SCH; candidates who took only one or two courses in Algebra scored higher than candidates who took three or more algebra courses. The most common course associated with higher scores in Domain III was Linear Algebra with 13/17 students who took only one or two courses in algebra taking this course.

Finally, there is a negative relationship between the 8-12 Mathematics TEXES Domain VI (Probability and Statistics) and SCH of algebra coursework. The highest scores in Domain VI are associated with 3-6 SCH and the most common course associated with higher scores for Domain VI was Linear Algebra with 12/16 students completed this course.

These overall results seem to suggest Linear Algebra is the most strongly related course for three of the six TExES Domains. If one course, Linear Algebra carries such a strong role in passing the state content exam, then perhaps policy makers should more closely examine the role of using the 8-12 Mathematics TExES as a measure of teacher knowledge and teacher quality.

Implications

For almost two decades Texas certification requirements for secondary mathematics teachers have included a degree in mathematics. Severe teacher shortages and *NCLB* requirements have increasingly lowered the bar for Texas teacher formal content preparation while elevating the role of teacher testing. In this study, ¼ of the candidates failed the 8-12 Mathematics TExES effectively allowing the examination to act as a gatekeeper for candidates who demonstrated high levels of course content completion while those with minimal preparation passed the examination.

Presently, the effect of such minimal coursework preparation on student achievement is unknown. Already, the *2006 Gap Analysis Report* of the North Texas Regional P-16 Council documents four years of achievement gaps existing in the state's K-12 public schools and charters: 1) African American and Hispanic students score lower than white students on all Texas Assessment of Knowledge and Skills (TAKS) indicators; 2) science and mathematics scores are much lower for African American and Hispanic students; and 3) lower percentages of African American and Hispanic students enroll in advanced courses, are tested in advanced placement courses, and achieve acceptable scores on national college entrance exams.

The strong association of Linear Algebra with three of the six TExES Domains warrants a review of the test standards as they relate to mathematics coursework. Policy makers are advised to consider the apparent lack of validity of the TExES as a measure of mathematics teacher knowledge and the pivotal role of mathematics coursework in providing teacher candidates with an "an opportunity to look deeply at fundamental ideas of mathematics, to connect topics which students often see as unrelated, and to develop the important mathematical habits of mind" (CBMS, 2001).

References

Aaronson, D., Barrow, L. & Sander, W. (2007). Teachers and student achievement in the Chicago public high schools. *Journal of Labor Economics*, *25*(1), 95-135.

American Council on Education (1999). To touch the future: Transforming the way teachers are taught. An action agenda for college and university presidents. Washington, DC: American Council on Education.

Angrist. J. D. & Guryan, J. (2007). Does teacher testing raise teacher quality? Evidence from state certification requirements. *Economics of Education Review*, *27*, 483-503.

Angrist, J. D. & Guryan, J. (2004). Teacher testing. Teacher education, and teacher characteristics. *American Economic Review, 94*(2), 241-46.

Barnett, J, & Hodson, D. (2001) Pedagogical Context Knowledge: Toward a fuller understanding of what good science teachers know. *Science Education 85*, 426-453.

Begle, E. (1979). Critical variables in mathematics education: Findings from a survey of the empirical literature. Washington, DC: The Mathematical Association of America and the National Council of Teachers of Mathematics. ED171515.

Betts, J., Zau, A., & Rice, L. (2003). Determinants of student achievement: New Evidence from San Diego. San Diego: Public Policy Institute of California. Retrieved from http://www.ppic.org/content/pubs/report/R_803JBR.pdf

Carpenter, T.P., Fennema, E., Peterson, P.I., & Carey, D.A. (1988). Teachers pedagogical content knowledge of students' problem solving in elementary arithmetic. *Journal in Mathematics Education 19*(5), 385.401.

Carpenter, T. P., Fennema, E., Peterson, P. L., Chiang, C. P., & Loef, M. (1989). Using knowledge of children's mathematics thinking in classroom teaching: An experimental study. *American Educational Research Journal*. *26.* 499-531.

Cavalluzzo, L.C. (2004). Is national board certification an effective signal of teacher quality? (Report No. IPR 11204). Alexandria, VA: CNA Corporation.

Clotfelter, C. T., Ladd, H. F. & Vigdor, J. L. (2006). Teacher-student matching and the assessment of teacher effectiveness. *Journal of Human Resources 41*(4), 778–820.

Cochran-Smith, M., & Zeichner, K. (2005). Executive summary: The report of the AERA panel on research and teacher education. In M. Cochran-Smith & K. Zeichner (Eds.), Studying teacher education (pp. 1-36). Mahwah, NJ: Lawrence Erlbaum.

Conference Board of the Mathematical Sciences. (2001). *The mathematical education of teachers*. Providence RI and Washington DC: American Mathematical Society and Mathematical Association of America. Retrieved from http://www.cbmsweb.org/MET_Document/chapter_9.htm.

Conference Board of the Mathematical Sciences. (2001). *The Mathematical Education of Teachers*. Retrieved from http://www.cbmsweb.org/MET_Document/chapter_5.htm.

Darling Hammond, L. (1999). *Teacher quality and student achievement: A review of state policy evidence*. (Report No. R-99-1). University of Washington: Center for the Study of Teaching and Policy.

Ferguson, P. & Womack, S. T. (1993). The impact of subject matter and education coursework on teaching performance. *Journal of Teacher Education, 44*(1), 55-63.

Franke, M.L., E. Fennema, T.C. Carpenter, E. Ansell, & Behrend, J. (1998). Understanding teachers' self-sustaining, generative change in the context of professional development. *Teaching and Teacher Education 14*(1), 67-80.

Frykholm, J.A., & Glasson, G.E. (2005). Connecting mathematics and science instruction: Pedagogical content knowledge for teachers. *School Science and Mathematics, 105*(3), 127-141

Fuller, E. (2008). Secondary mathematics and science teachers in central Texas: Supply, demand, and quality. Department of Educational Administration, University Council for Educational Administration, The University of Texas at Austin.

Goldhaber, D. D. & Brewer, D. J. (1997). Teacher licensing and student achievement. In M. Kanstoroom,& C. E. Finn. (Eds.), *Better Teachers Better Schools*. (pp. 83-103). Washington, DC: Thomas B. Fordham.

Goldhaber, D.D. & Brewer, D.J. (2000). Does teacher certification matter? High school certification status and student achievement. *Educational Evaluation and Policy Analysis, 22*(2), 129-145.

Goldhaber, D. (2007). Everyone's doing it, but what does teacher testing tell us about teacher effectiveness? *The Journal of Human Resources 42*(4), 765-794.

Harris, D. N., & Sass, T. R. (2007). *Teacher training, teacher quality and student* achievement (Working Paper No. 3). Washington, DC: National Center for Analysis of Longitudinal Data in Education Research. Retrieved from http://www.caldercenter.org/publications.cfm.

Interstate New Teacher Assessment and Support Consortium (INTASC). Mathematics subcommittee (1993). *Model standards for beginning teacher licensing and development: A resource for state dialogue*. Washington DC: Council for Chief State School Officers.

Kinach B. M. (2002). A cognitive strategy for developing pedagogical content knowledge in the secondary mathematics methods course: Toward a model of effective practice. *Teaching and Teacher Education, 18*(1), 51-71.

Nakiboglu, C. & Karakoc, O. (2005). The fourth knowledge domain a teacher should have: The pedagogical content knowledge. *Theory & Practice 5*(1), 201-206.

Monk, D. (1994). Subject area preparation of secondary mathematics and science teachers and student achievement. *Economics and Education Review*, *13*, 125–145.

National Board for Professional Teaching Standards (1993). *What teachers should know and be able to do*. Detroit: National Board for Professional Teaching Standards.

National Council for Teachers of Mathematics (1991). *Professional standards for teaching mathematics.* Reston, VA: National Council for Teachers of Mathematics.

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics.* Reston, VA: National Council of Teachers of Mathematics.

National Council for Teachers of Mathematics (2003). *Programs for initial preparation of mathematics teachers*. Retrieved from http://www.ncate.org/ProgramStandards/NCTM/NCTMSECONStandards.pdf

National Commission on Teaching and America's Future (1996). *What matters most: Teaching for America's future.* New York: National Commission on Teaching and America's Future.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Texas Administrative Code. Title 19, Part 7, Chapter 227, Rule §227.10 (3) (C).

Texas Education Code. High school graduation requirements. §74.63 (2007).

Texas Higher Education Coordinating Board (2009). *Coordinating board and State Board for Educator Certification requirements for approval of new or revised undergraduate degree programs leading to teacher certification in Texas (EC-4, 4-8, 8-12, EC-12 Programs)*. Retrieved from http://www.thecb.state.tx.us/reports/PDF/0969.PDF.

The Glenn Commission National Commission on Mathematics and Science Teaching for the 21st Century (2000). *Before it's too late*. Retrieved from http://www.ed.gov/inits/Math/glenn/report.pdf.

University of North Texas Undergraduate Catalog (2009). Retrieved from http://www.unt.edu/catalog/undergrad/math.htm

Veal, W. R., & Kubasko, D. S. (2003). Domain specific pedagogical content knowledge of evolution held by biology and geology teachers. *Journal of Curriculum and Supervision 18*(4), 334-352.

Wenglinsky, H. (2000) How teaching matters: Bringing the classroom back into discussions of teacher quality (Policy Information Center Report). Princeton, NJ: ETS. Retrieved from http://www.ets.org/Media/Research/pdf/PICTEAMAT.pdf.

Wenglinsky, H. (2002). How schools matter. The link between teacher classroom practices and student academic performance. *Education Policy Analysis Archives, 10*(12). Retrieved from http://epaa.asu.edu/epaa/v10n12/.

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