Mathematics Classes for Future Elementary Teachers: Data from Mathematics Departments

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Mathematicians have a unique opportunity to influence elementary teachers' mathematical knowledge. Nearly all future teachers are required to take mathematics courses in their undergraduate education, and many take courses specifically required for elementary certification. Even in this era of alternative certification, a majority of teachers come to their first job from a four-year teacher certification program in which one or more mathematics courses are required.[1] According to the Conference Board of the Mathematical Sciences (CMBS) 2005 survey of U.S. mathematics departments, 87% of mathematics departments in the United States are in institutions that certify elementary teachers, and of these, 86% offer a special course or sequence of mathematics courses for K–8 teachers (Lutzer, Rodi, Kirkman, & Maxwell, 2007, pp. 49–50). Mathematics departments design and teach these courses and thus can make a huge difference across the United States in what is offered to, and expected of, future elementary teachers.

The responsibility for educating future elementary teachers is shared by institutions across the country and impacts education in every state. Recent data from Title II reporting (`title2.ed.gov`) show that new teachers are now a mobile population, with almost every state importing teachers from other states, and even from other countries. For example, Michigan, where unemployment is high and the teacher population shrinking, exports most of its newly certified teachers to other states, and South Carolina has been bringing in teachers from other states for many years (although this may have changed in the current economic downturn). It is no longer accurate to assume that teachers will stay close to home. We cannot conclude, even if our state or institution is doing a good job, that the mathematical education of elementary teachers is someone else's problem.

Concern about teachers' mathematical knowledge has increased dramatically over the last two decades as U.S. scores on international assessments have slipped relative to other countries. Attention to the problem has led to recognition that it takes more than competence in arithmetic to teach elementary school mathematics successfully. At least since Ball's early work on teacher knowledge (Ball, 1988, 1990) and Ma's book that followed up on Ball's work (Ma, 1999), mathematicians and mathematics educators alike have acknowledged both the importance of elementary school teachers' mathematical knowledge and the nontrivial task of helping teachers learn what they need to know.

In spite of the interest in teachers' mathematical knowledge, information about mathematics courses for future teachers is sparse. The CBMS

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A longer version of this paper is available on the project website, `http://meet.educ.msu.edu`.

[1] *Data from the Title II reporting system* (`title2.ed.govesecReport06.asp`) *show that in 2004, a total of 310,000 teachers received initial certification in the fifty states. Of these, 35,000 were reported as "alternative route" certifications, 11% of the total. Although the number of alternate-route certifications is growing, most teachers will continue to be certified through "traditional" routes for some years to come, providing an important site for improving teachers' mathematical knowledge.*

survey provides the only systematic data about these courses, and it includes only a few questions related to the mathematical education of elementary teachers. Among the things we do not know are: what textbooks are typically used; who teaches the courses (e.g., mathematicians, mathematics educators, graduate students, etc.) and what their qualifications are; what topics are covered, in what depth, and for what purposes; what (and whether) the future teachers actually learn from these courses.

This article reports on part of a study of undergraduate mathematics courses for future elementary teachers (the Mathematical Education of Elementary Teachers, MEET, project). In the larger study, we collected achievement data via pre- and posttests of undergraduate students in mathematics courses required for certification. Those data show that students in such courses make significant gains in their mathematical knowledge, especially in courses that use one of the textbooks written specifically for mathematics courses for elementary teachers (complete reports on the achievement data, instructor survey, and department survey are available on the project website, `http://meet.educ.msu.edu`). Here, we report on data from mathematics departments that offer such courses, with a particular eye on how they structure and staff these courses and how the courses differ across institutions. We also include data from the CBMS 2005 survey of mathematics departments to draw attention to the fact that the CBMS survey, completed every five years, has data of interest to mathematicians who design and teach courses for future elementary teachers.

Data

For the MEET project, we surveyed mathematics departments in 2006–7, prior to other data collection. The data come from South Carolina, Michigan, and New York City, sites chosen because of their varying approaches to improving teacher quality. In these three sites, we identified all undergraduate institutions that offer elementary certification and contacted the mathematics department chair to participate in the survey. Of the seventy institutions that have undergraduate certification programs, fifty-seven (81%) responded to our survey, which was conducted over the telephone. The department chair or someone designated by the chair—the program coordinator, a staff member, or another faculty member—answered our questions about the curriculum and instructors of these mathematics courses, with detailed questions about a focal course in which we later collected data from instructors and students. The focal course was usually the first (or only) mathematics course required for elementary certification, excluding prerequisites or general education courses that constituted distribution requirements. For example, at Michigan State University (where the first author is a faculty member), two mathematics courses are required for elementary certification, but a prerequisite for the first course is either satisfactory completion or testing out of college algebra. In such a case, the focal course is the first of the two courses required for certification, not the college algebra course.

Survey data were complemented by information from *U.S. News and World Report*[2] about school

Table 1
Number of Institutions by Size, Selectivity[a]*, and Carnegie Classification*[b]

Characteristic	All	Bachelor's	Master's	Ph.D.
All institutions	57	17	26	14
Size of elementary cohort (students admitted in a given year)				
Less than 50	27	14	10	3
50–149	15	3	10	2
150 or more	15	0	6	9
Selectivity of institution				
Less selective	11	4	7	0
Selective	29	7	15	7
More selective	17	6	4	7

[a]Selectivity is derived from *U.S. News* categorizations. We combine their five categories to form three categories as follow: *U.S. News* "Most" and "more" selective were combined to form "More selective"; their "selective" was used for our "selective" category; and their "less" and "least" selective were combined to form our "Less selective". The *U.S. News* categories are derived from reported acceptance rates.

[b]The Carnegie classification indicates the highest degree awarded by the institution (e.g., a bachelor's institution does not award master's or doctoral degrees, and a master's institution may offer both a bachelor's and master's degree). Regardless of the institution's Carnegie classification, the programs described here are undergraduate (i.e., bachelor's level) programs.

selectivity; from the Carnegie Foundation for the Advancement of Teaching[3] to classify schools by their highest degree offered; from the U.S. Title 2 website[4] to ascertain the number of elementary candidates and institutional certification requirements; and from state websites to determine statewide certification requirements. Table 1 shows basic data about the institutions included in our sample.

The variability of access to information about certification requirements proved to be both interesting and challenging. It is extremely hard to find in some states (Michigan) and quite easy in others (New York). At the start of the project, before states were selected (2004–5), we investigated more than twenty states in depth and found that the information available to prospective teachers is often obscure if not impossible to find and/or decipher. Although certification requirements address so many different contingencies and thus are complex, it seems counterproductive to make it so hard for prospective teachers to learn what they need to do to become teachers. New York has one of the best systems[5] we have seen, available on the Web to anyone who is interested, while Michigan has one of the worst.

In our interviews with mathematics department chairs, we found a high level of involvement and knowledge about the mathematical education of teachers. The reported schism between mathematicians and mathematics educators did not hold true in this sample of schools. Department chairs knew the details of their programs for elementary education students and were committed to the importance of their work in educating these future teachers, and this was true across the board, from large public Ph.D. institutions to small private schools. Whether from the chair or a designated representative, we heard many passionate explanations of the importance of these courses and the struggles departments experience as they try to ensure that elementary teachers are qualified to teach mathematics. We learned of departments that offer extensive tutoring, high-stakes computation tests with multiple chances to achieve mastery, instructor-written textbooks or materials, and many more examples of efforts aimed at solving the complex problems of the mathematical education of elementary teachers.

[2]`www.usnews.com/usnews/edu/college/rankings/rankindex_brief.php`, *2006 version.*

[3]`www.carnegiefoundation.org`

[4]`www.title2.org`. *Teacher education institutions in the United States are required to make annual reports to the federal government, and data from these reports are made available on the Title 2 website.*

[5]*Available at* `http://eservices.nysed.gov/teach/certhelp/CertRequirementHelp.do`

Selected findings from the survey are reported briefly here, with particular attention to the following questions:

1. How many mathematics courses are required for future elementary teachers?
2. What is the typical content of these courses?
3. Who teaches the courses?

1. How many mathematics courses are required for future elementary teachers?

Determining and comparing the number of courses required for elementary certification is complex, even when information is readily available, because of variation in how teaching certificates are awarded. In some states, elementary teachers are certified to teach all subjects, K–8. In other states, the certification is divided into lower grades (e.g., K–3) and upper grades (4–8), with different requirements for the two levels. In many states, middle school (typically grades 6–8) teachers can be certified either as secondary subject teachers (e.g., in mathematics) or as elementary teachers who can teach any subject. Sometimes, teachers with a general K–8 certification are required to have a specialization in mathematics to teach middle school mathematics. In other states, prospective elementary teachers are required to have a major or minor in mathematics, in addition to other requirements for elementary certification, in order to teach mathematics at the middle school level. In our data, as in the CBMS survey, we distinguish between institutions based on whether the requirements vary for those who are certified to teach early grades and those certified to teach later grades, including middle school.

In recent years, more states have been requiring subject matter specializations for middle grade teaching. Michigan and New York both have a middle school mathematics certification requirement, and, at the time of the survey, South Carolina was phasing in a policy that was to be completely implemented by 2008. Michigan requires a mathematics major (thirty hours minimum) or minor (twenty hours minimum) and satisfactory performance on the Michigan subject area test for middle school mathematics teaching. New York requires thirty semester hours of mathematics, student teaching specifically in middle school mathematics, and acceptable performance on the New York mathematics content area test. In South Carolina, the policy requires an undergraduate major in mathematics and satisfactory performance on the PRAXIS II content area test.[6, 7]

The CBMS 2005 survey found that 44% of four-year institutions that certify elementary

[6]*PRAXIS II is a test administered by the Educational Testing Service, ETS, and used by a number of states in the United States to assess prospective teachers' knowledge. See* `http://www.ets.org/praxis`.

teachers have different requirements for early and later grades, with an average of 2.1 mathematics courses required for certification in institutions with a single certification requirement; an average of 2.7 courses in institutions that offer early elementary certification (up from 2.4 in 2000); and 5.6 courses for the later grades certification (up from 3 in 2000; p. 52). In our sample, 36% of institutions had different requirements for later grades. Numbers of required courses are shown in Table 2, with a breakdown of the MEET data by Carnegie classification and selectivity, with requirements for math specialization shown separately.

In the MEET survey, the number of courses required for basic K–8 certification ranged from zero to six, with fifty-five of the fifty-seven schools offering courses specifically designed for elementary teachers. This concurs with the CBMS data, in which 81% of certifying institutions offered a special course or course sequence for future elementary teachers. The most common requirement was two courses, but three institutions required no mathematics (other than general distribution requirements for all students) and one institution required six classes. Table 2 shows that the mean number of required courses is 2.2, with over a third of the institutions offering a specialization with much greater course requirements. Ph.D. institutions and larger schools are more likely to offer mathematics specializations, for which the mean number of required mathematics courses is 6.9. While bachelor's institutions are least likely to offer mathematics specializations to elementary teachers, those that do have more course requirements (9.5) than doctoral institutions (6.3). The same pattern is present when comparing institutions by size. Institutions with over 150 elementary education graduates each year are the most likely to offer math specializations but require students to take fewer courses for the major than smaller programs.

Statistical (chi-square) analysis of the data show that the percentage of institutions with mathematics specialization differs significantly by Carnegie classification ($p < 0.05$ that these differences occurred by chance; the statistic indicates that at least one of the three numbers differs significantly from the others) and by size of the elementary cohort ($p < 0.01$ that the differences occurred by chance, again indicating that at least one of the

[7] *There are similar problems with counting courses, since the number of contact hours can vary considerably. Some institutions use a semester system, others a quarter system. Courses can meet from one to more than five hours a week with different associated credit hours. Adopting methods from the CBMS survey, we report number of required courses. In other parts of the study, we asked about contact hours, credit hours, and semester v. quarter requirements, but we report only number of courses here.*

Table 2
Number of Required Mathematics Content Courses by Institutional Characteristics[1]

	Number of institutions (n)	Number of courses for basic certification		Percent with mathematics specialization	Number of courses for mathematics specialization
		Mean	SD	Percent	Mean
All Institutions	57	2.2	1.20	37	6.9
Carnegie classification					
Ph.D.	14	2.0	.96	50*	6.3
Master's	26	2.3	.79	46*	6.8
Bachelor's	17	2.1	1.80	12*	9.5~
Size of elementary cohort					
Less than 50	27	1.9~	.84	16**	8.0
50–149	15	2.7	1.63	40**	7.5
More than 150	15	2.3	1.07	71**	5.9~
Selectivity of institution					
Less selective	11	2.2	.75	18	7.0
Selective	29	2.1	.83	38	6.6
More selective	17	2.2	1.86	47	7.4

[1] *All but one of the schools in the sample reported a semester schedule. The one different school was on a 4-1-4 schedule. Numbers have not been adjusted to reflect this difference.*

~ $p < 0.1$ for t-test statistic comparing the mean of institutional type to other types.

** $p < 0.05$, **$p < 0.01$ for chi-square statistic indicating the distribution varies by this institutional type.*

three numbers differs significantly). The latter may reflect that the larger institutions are able to require a specialization because they have the student populations to do so. The difference by Carnegie classification suggests that Ph.D. and master's institutions may be better able to adopt policy and research recommendations for increasing the preparation of middle school mathematics teachers than bachelor's institutions, and this may be related to size. T-tests of the difference of means show that the average of 9.5 courses required by bachelor's institutions for a mathematics specialization is significantly different from the other means with less than a 0.1 probability that the difference occurred by chance; and that the average of 5.9 courses required by the institutions with the largest cohorts is significantly less than the number required by the institutions with smaller cohorts. At the same time, the mean of 1.9 courses required for basic certification in schools with the smallest cohorts is statistically different from requirements at schools with larger cohorts. These statistics show that, in this sample, bachelor's institutions and smaller institutions that offer a specialization for later grades are requiring much more mathematics than schools in the other categories. Selectivity of institution shows no significant differences for the likelihood of offering a specialization, or for the number of courses required when the specialization is offered.

What do these data mean? It is hard to interpret definitively, but it is clear here, as in the CBMS data (and using earlier CBMS data as a comparison), that the mathematics requirements for certification are increasing at all kinds of institutions. The specialization requirements are close to seven courses, which could be a respectable minor of twenty-one credits in many schools. The number of courses required for basic certification is still well below CBMS recommendations, especially for the schools in the sample with smaller cohorts.

We asked about the size of classes and the number of sections and found that the mean size was twenty-six students per section, and the mean number of sections was four. The largest class in our sample was sixty, and the smallest fifteen. Both the class size and the number of sections varied by size of the institution, with smaller schools having both fewer sections and smaller class size. In no case in our data did we find classes that met as a large lecture with discussion sections. That is, the sections were independent classes with their own instructors.

2. What is the typical content of these courses?

We asked the department chairs about the content of the course or sequence of courses required for certification and found that 51% of the focal (usually first) courses focused primarily on number and operations, and 41% of the second courses focused on geometry and measurement. Table 3 shows the results across all topics. We asked about both the primary content of the course and the secondary content. As the table shows, there

Table 3
Percent of Institutions with Specific Content Focus by Content and by Course

	Focus in required courses by content		Primary content focus by course	
	Primary content	Secondary content	Focal course	Second course
Data and statistics	17%	22%	6%	26%
Number and operations	25	14	51	10
Problem solving[a]	10	21	19	5
Number theory	7	23	11	5
Geometry and measurement	22	22	8	41
Algebra and prealgebra	8	22	11	5
Logic and/or set theory	6	17	13	0

Note: Respondents were asked to choose one primary content area. However, some respondents indicated two content areas of equal importance and could not choose just one area. For this reason, the percentages of primary content area do not add to 100. The percentages for secondary content area do not add to 100 because respondents were allowed to choose multiple areas.

[a] We include problem solving as a separate content area because, in fact, we found that some courses (and textbooks) do not have a topical focus but rather are problem-based and range across topics, with the focus on problem solving as a process.

Table 4
Textbook Used by Number of Institutions

Book	Percent of institutions	Number of institutions
Billstein et al.	21%	12
Musser et al.	11	6
Other mathematics for elementary education textbook	19	11
Other mathematics textbook	30	17
No textbook	19	11

is considerable attention to number and operations, geometry and measurement, and data and statistics, with other topics included but less often as a focal topic.

Another way to understand the content of the courses is to examine the textbooks and other materials used. We found that most of the courses (83%) use a single textbook for the course and that in schools with multiple sections, all instructors use the same text. Textbook use data are shown in Table 4.

The most commonly used textbook was Billstein, Libeskind, and Lott (2004), and the second most popular was Musser, Burger, and Peterson (2003). Twenty-nine of the schools used textbooks such as these two, written specifically for mathematics courses for teachers, but as shown in the table, seventeen used other mathematics textbooks, and eleven used no textbook. In the last category, schools that did not use a textbook typically used materials developed by the instructor or department or a collection of books and resources, not including a textbook per se. One important finding from analysis of the achievement data is that students in classes that use one of the thirteen textbooks specifically designed for such a class (e.g., the twenty-nine cases shown in the table above) make significantly higher gains than those in classes with other textbooks or no textbook at all. Unfortunately, we did not have enough data to analyze the results by specific textbook to see whether any single book, or subgroup of books, resulted in higher performance.

3. Who teaches the courses?

We asked about the positions held by instructors of the courses and how the department went about staffing. For these data, we asked the respondent about the specific individuals teaching the required courses during the 2006–7 academic year. Data reported here are for all instructors ($n = 81$), not for individual institutions. Fifty-nine percent of the instructors were tenured or tenure-eligible faculty in the mathematics department. The other categories are: other full-time with Ph.D. (5%), other full-time without Ph.D. (13%), part-time faculty (20%), and graduate teaching assistant (4%). The part-time faculty were typically adjuncts who had K–8 classroom experience. These percentages varied significantly by Carnegie classification, where master's and bachelor's institutions had higher percentages of tenure-stream faculty teaching and no graduate assistants; and by size, where smaller institutions had more tenure-stream faculty teaching these courses.

Even though all of the courses were taught in mathematics departments, the degrees of the instructors were not all in mathematics. In the Ph.D. category, nineteen of the forty-seven instructors with Ph.D.s. had Ph.D.s in mathematics, twenty-two in mathematics education, and six in other subjects. Overall, fifty of the eighty-one instructors had at least one degree in mathematics.

One of the questions posed to the department chair (or representative) was about the difficulty of staffing the courses. Fifty-seven percent of the departments reported that it was easy to staff, and 19% reported that it was very difficult. This varied considerably by institution type: only 11% of departments in Ph.D. institutions reported that it was easy to staff the courses, while 80% of the bachelor's institutions did so. The issues surrounding teaching courses for elementary teachers depend on the other obligations and interests of faculty members beyond undergraduate teaching.

Conclusions

The efforts of these department chairs and instructors, combined with increases in the numbers of required courses and in state mandates to staff later grades with teachers who have specializations in mathematics, may bear fruit in the future as the number of teachers who know more mathematics increases in classrooms across the country. Although progress in changing the mathematical profile of elementary school teachers will be slow as new graduates replace retirees and others who leave the profession, it is critical for mathematicians to continue their involvement with designing and teaching these courses so that every newly certified teacher will be prepared to teach rigorous, accurate, and interesting mathematics to their young students.

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About the Cover

2D vortex formation

This month's cover is a sequence of images of simulated vortex formation in two dimensions. Red patches indicate counterclockwise rotation, blue clockwise. They illustrate that in two dimensions, vortices initially randomly distributed will coalesce. This is the theme of the article by C. Eugene Wayne in this issue.

The images are from an animation produced by Herman Clercx and GertJan van Heijst of the Fluid Dynamics Laboratory at TU Eindhoven. A link to the animation can be found at Figure 6 on the webpage `http://web.phys.tue.nl/nl/de_faculteit/capaciteitsgroepen/transportfysica/fluid_dynamics_lab/turbulence_vortex_dynamics/2d_turbulence/bounded/`.

For more information, see the paper "Self-organization of quasi-2D turbulence in stratified fluids in rectangular containers" by Clercx, van Heijst, and S. R. Maassen in the *Journal of Fluid Mechanics* (volume 495, 19–33, 2003).