# THE STATUS OF CAPSTONE COURSES IN THE PREPARATION OF SECONDARY MATHEMATICS TEACHERS

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*For more than a decade, capstone courses have been recommended as a way for pre-service secondary mathematics teachers to connect the mathematics they learn in college to the mathematics they will teach in their own classrooms. Yet little is known about the extent and nature of the implementation of these courses in the United States. This paper presents findings from a 2011 survey of U.S. colleges and universities that investigated whether and how capstone courses for pre-service secondary mathematics teachers have been implemented.*

*Keywords: capstone course, mathematics teacher preparation, secondary mathematics*

In 2001, the Conference Board of the Mathematical Sciences (CBMS) recommended that pre-service high school teachers complete "a 6-hour capstone course connecting their college mathematics courses with high school mathematics" (p. 8). Since that time, there have been a handful of reports on implementations of individual courses that fit this description (e.g., Artzt, Sultan, Curcio, & Gurl, 2011; Hill & Senk, 2004; Loe & Rezak, 2006; Shoaf, 2000; Van Voorst, 2004). However, the status of the mathematics capstone course in the United States is largely unknown. There has, thus far, been no systematic study of the extent or characteristics of its varied implementations.

Herein, we present results from a 2011 survey of colleges and universities that may offer an upper-level capstone course, either in the mathematics department or in the college of education, for mathematics majors intending to be secondary teachers. The goal of the survey was to investigate the status of capstone courses in the United States and the extent to which the CBMS recommendations align with the capstone courses in our sample. For the purposes of the survey, we defined a *capstone* as a course taken at the conclusion of a program of study for pre-service secondary mathematics teachers that places a primary focus on providing at least one of the following: (1) bridges between upper-level mathematics courses, (2) connections to high school mathematics, (3) additional exposure to mathematics content in which students may be deficient, or (4) experiences communicating with and about mathematics (Loe & Rezac, 2006).

The survey, which can be found in Appendix A, investigated the prevalence and nature of courses fitting this description. In particular, the survey included questions about capstone characteristics such as the department, title, duration, textbook(s), and other resources used in the course. It also included questions related to the nature of the course; specifically, data was collected about the description of the capstone course in the university's catalog, the course goals, the instructional style, and the content. To provide a more complete picture of the current state of capstone courses, data was also collected about instructors' backgrounds and their levels of academic freedom.

## Perspective

Secondary mathematics teacher preparation programs typically require pre-service teachers to complete a mathematics major, or the equivalent (Artzt, Sultan, Curcio, & Gurl, 2011; CBMS, 2001). However, there is some uncertainty about the value of a traditional

mathematics undergraduate degree for secondary mathematics teachers. The CBMS (2012), echoing the concerns of Felix Klein (1932), described a "double discontinuity" often encountered by secondary mathematics teachers. The first is when they transition from high school mathematics to seemingly disconnected university mathematics courses. The second occurs when new teachers, upon beginning their careers, experience a disconnect between the mathematics learned in university courses and the mathematics of high school. These ideas align with Monk's (1994) influential report which placed doubt on the value of the upper division mathematics courses for preparing effective mathematics teachers. Among the conclusions from the large-scale longitudinal study, Monk declared that "having a mathematics major has no apparent effect on student performance" (p. 132).

Hodgson (2001) noted that pre-service secondary mathematics teachers "have no explicit occasion for making connections with the mathematical topics for which they will be responsible in school, nor of looking at those topics from an advanced point of view" (p. 509). He endorsed the inclusion of undergraduate coursework to help pre-service teachers develop "deep conceptual understanding of the school mathematics content" (p. 512). The CBMS (2001) recommendation for capstone courses arose from a similar recognition that an undergraduate degree in mathematics may not help pre-service teachers develop this deep and relevant knowledge prior to entering their profession. A decade after this recommendation, the survey reported herein provides insight about the status of the capstone course for pre-service secondary mathematics teachers.

## Methodology

From the 1,713 institutions listed by the Carnegie Foundation for the Advancement of Teaching (Carnegie Classifications, 2011), we selected a stratified random sample of 200 institutions, weighted appropriately for each of nine classification groups (e.g., PhD granting institutions with high research activity, Master's Colleges and Universities-larger programs). A 23 question survey (see Appendix A) was developed using Qualtrics online survey software and sent to each of these 200 institutions. The first two questions (P1 & P2) inquired about whether the institution has a capstone course. Institutions with capstones were then prompted to answer 21 additional questions (Q1 though Q21). As only 32 of these 200 institutions responded, the sample was expanded to a total of 73 by sending the survey to three relevant email listservs. This second phase of solicitation altered our initial plan for random sampling; our ability to make inferences has, thus, been hindered. However, the sample provided rich data which was analyzed in Excel using basic summative statistics. The responses for each of the 21 survey questions were analyzed separately by at least two team members. The analyses were then compared, merged, and summarized by the research team.

## Results

The survey was completed by individuals at 73 distinct colleges and universities. Of these institutions, 42 (57.5%) reported having a content course, taken at the conclusion of a program of study for pre-service secondary mathematics teachers, that satisfies at least one of the goals that Loe & Rezac (2006) described for their capstone course. That is, each of the 42 institutions has a course intended to provide at least one of the following:

1. bridges between upper-level mathematics courses,
2. connections to high school mathematics,
3. additional exposure to mathematics content in which students may be deficient, or
4. experiences communicating with and about mathematics.

The respondents represented a variety of institutions, as reflected in the 2011 Carnegie classifications; this data is summarized, along with additional information, in Table 1.

Among the 42 institutions reporting capstone courses, one submitted separately about two different courses, and two did not provide any additional details about their courses.

**Table 1. Summary of the sample.**

| Carnegie Type | All | Have Cap-stone | CBMS |
|---|---|---|---|
| Bac/A&S: Baccalaureate Colleges--Arts & Sciences | 12 | 6 | 0 |
| Bac/Assoc: Baccalaureate/Associate's Colleges | 3 | 1 | 0 |
| Bac/Diverse: Baccalaureate Colleges--Diverse Fields | 8 | 7 | 6 |
| Master's L: Master's Colleges and Universities (larger programs)* | 24 | 15 | 10 |
| Master's M: Master's Colleges and Universities (medium programs)* | 7 | 5 | 3 |
| Master's S: Master's Colleges and Universities (smaller programs) | 4 | 3 | 2 |
| DRU: Doctoral/Research Universities | 3 | 0 | 0 |
| RU/H: Research Universities (high research activity) | 3 | 3 | 3 |
| RU/VH: Research Universities (very high research activity) | 8 | 2 | 2 |
| Spec/Faith: Special Focus Institutions--Theological seminaries, Bible colleges, and other faith-related institutions | 1 | 0 | 0 |
| TOTAL | 73 | 42 | 26 |

* Each of these categories has one respondent that has a capstone but did not answer follow-up questions; it is unknown whether they align with the CBMS recommendation.

*CMBS versus non-CBMS.* As our survey defined a capstone course more broadly than the CBMS recommendation, most of the results reported below make a distinction between what we have labeled as CBMS and non-CBMS courses. A CBMS course is one that aligns with the CBMS recommendation of "connecting [students'] college mathematics courses with high school mathematics" (2001, p.8). By parsing the data in this way, we were able to separately comment on the statuses of capstone courses which align with the CBMS recommendation and those self-identified capstones which do not. This criteria was operationalized in question Q7 (see Appendix A), which investigated the purposes of the course. Table 2 summarizes responses to Q7 and lists the six capstone course purposes which followed Q7's instructions to "check all that apply." The first four purposes align with capstone goals enumerated by Loe and Rezac (2006). Capstone courses which had purpose (b) were classified here as CBMS courses; a non-CBMS course is one which aligns with at least one of the other purposes, but does not align with purpose (b). There were 41 responses about capstone course goals; of these 41 capstones, 26 were categorized as CBMS courses. A mean of 3.2 goals were chosen per course.

**Table 2. Purpose of the capstone (n=41).**

| Purpose of capstone is to provide: | n | % |
|---|---|---|
| (a) bridges between upper-level mathematics courses, especially real analysis, abstract algebra, probability/statistics, and geometry | 22 | 54% |
| (b) an opportunity to explore connections between college mathematics and secondary school mathematics | 26 | 63% |
| (c) additional exposure to areas of mathematics in which they may be deficient | 24 | 59% |
| (d) research and writing in mathematics and with making oral presentations to their peers and instructors | 33 | 80% |
| (e) the opportunity to learn pedagogical principles for teaching secondary mathematics | 9 | 22% |
| (f) opportunities to become familiar with technology for teaching | 9 | 22% |
| (g) other | 8 | 20% |

*Capstone Course Goals.* The CBMS vs. non-CBMS distinction was apparent in the results of question Q8 which investigated the goals of the capstone courses (see Table 3). Goals (b) and (e) in Table 3 correspond to the CBMS recommendations and were much more prevalent in the CBMS courses. The most common goal for both CBMS and non-CBMS courses was for students to develop a deeper understanding of mathematics. Survey respondents were given an opportunity to name goals that were not given in the survey list. Examples of non-CBMS goals included student investigation of a substantial mathematics topic and learning advanced mathematics on their own, while an example of a CMBS goal was clearly writing mathematics.

**Table 3. Goals of capstones.**

| Goals | All | CBMS | non-CBMS |
|---|---|---|---|
| (a) Students are knowledgeable about the university mathematics content addressed in the course | 56% | 50% | 67% |
| (b) Students take an in-depth look at some mathematical topics which are particularly important in secondary mathematics | 56% | 77% | 20% |
| (c) Students know how to use a variety of teaching strategies when teaching mathematics | 15% | 23% | 0% |
| (d) Students can (effectively) integrate technology into their future classrooms | 24% | 35% | 7% |
| (e) Students connect appropriate college mathematics content to high school mathematics content and pedagogy | 46% | 69% | 7% |
| (f) Students become aware of current topics and issues in secondary school mathematics | 17% | 23% | 7% |
| (g) Students develop a deeper appreciation of mathematics | 85% | 81% | 93% |
| (h) Students develop a personal philosophy to support the teaching of secondary mathematics | 20% | 27% | 7% |
| (i) Other | 20% | 8% | 40% |

| | | | |
|---|---|---|---|
| n | 41 | 26 | 15 |

*Length of the capstone course.* The majority of capstone courses in our sample were offered as one-semester or one-quarter classes. A larger proportion of CBMS capstone courses (73%) were single courses, whereas half of non-CBMS capstone courses spanned more than one semester. Data about the number of capstone semesters/quarters are summarized in Table 4. The survey also revealed a wide range of times since the capstone was first offered at the institutions in the sample, from one to more than twenty years. Across all institutions, the capstone courses had existed for a median of seven years. For CBMS capstone courses, the median length of existence was six years; non-CBMS capstone courses existed for a median of ten years.

**Table 4. Number of capstone semesters/quarters (n=40 institutions).**

| # of courses | All | CBMS | non-CBMS |
|---|---|---|---|
| 1 | 26 | 19 | 7 |
| 2 | 11 | 5 | 6 |
| 3 | 2 | 1 | 1 |
| 4 | 1 | 1 | 0 |
| Total | 40 | 26 | 14 |

*Capstone course resources.* The resources used to develop the courses are summarized in Table 5. On average, CBMS capstone courses were developed in consultation with three of the listed resources, where non-CBMS capstone courses were developed with a mean of 1.5 resources. The development of CBMS courses was, to a much larger extent, guided by national organizations and recommendations, as well as by high school standards. Four courses (three CBMS) were developed in consultation with education departments; other departments consulted were communications (CBMS) and science departments (non-CBMS).

**Table 5. Resources used to develop course (n=41 capstones).**

| Resources used to develop course | All | CBMS | non-CBMS |
|---|---|---|---|
| National guidelines | 13 | 11 | 2 |
| Common Core State Standards | 9 | 9 | 0 |
| National Council of Teachers of Mathematics | 17 | 17 | 0 |
| Conference Board of the Mathematical Sciences | 11 | 8 | 3 |
| Mathematics Association of America | 22 | 14 | 8 |
| National Mathematics Advisory Board Recommendations | 6 | 4 | 2 |
| Collaboration with other departments on campus | 8 | 6 | 2 |
| Collaboration with other universities | 5 | 4 | 1 |

*Capstone course students.* Twelve capstone courses, all of which were CBMS courses, were described as being required specifically for pre-service mathematics teachers. At the non-CBMS schools, all of the students who enrolled in the courses were mathematics majors. At most schools (both CBMS and non-CBMS), students intending to be mathematics teachers did not exclusively populate the capstone courses. Indeed, only six capstone courses (all

CBMS) reported that they are exclusively for students seeking teaching licensure. Two of the non-CBMS courses did not include any category of students seeking licensure. Table 6 lists the percentages of capstone courses in our sample that included various categories of students.

**Table 6. Students to whom the capstone is available.**

| Who takes the course? | All | CBMS | non-CBMS |
|---|---|---|---|
| Alternate licensure students post-baccalaureate | 22% | 31% | 7% |
| Graduate students | 10% | 12% | 7% |
| Undergraduate math majors | 80% | 69% | 100% |
| Undergraduate math majors pursuing teaching licensure | 83% | 85% | 80% |
| Undergraduate mathematics education majors pursuing teaching licensure | 59% | 65% | 47% |
| Undergraduate math minors | 34% | 31% | 40% |
| Undergraduate math minors pursuing licensure | 27% | 31% | 20% |
| n | 41 | 26 | 15 |

*Capstone course prerequisites.* Our expectation was that the capstone course, as defined in this survey, is typically intended to be taken at the conclusion of a program of study for pre-service secondary teachers. Therefore, our survey probed the prerequisites for these courses. Five responses stated only that advanced standing was required; these responses have been eliminated from

Table 7, which provides details about prerequisites. Calculus and linear algebra were the most commonly listed prerequisites. The one capstone course which did not include calculus as a prerequisite required a mathematics course specifically for pre-service mathematics teachers and six additional units of unspecified mathematics.

Some features of this list of prerequisites stand out, particularly when comparing CBMS to non-CBMS courses. The CBMS capstone courses were twice as likely to have non-Euclidean (rather than Euclidean) geometry as a prerequisite. These two geometry courses were equally likely prerequisites among the non-CBMS courses. Calculus-based statistics was more popular as a prerequisite among CBMS courses; eight of the nine non-CBMS courses which required statistics did not require it to be calculus-based. If Probability, Calculus-Based Statistics, Non-Euclidean Geometry, Abstract Algebra, and Real Analysis are counted as upper-division courses, then 31% of all capstone courses reported no upper division prerequisites. This rate was consistent among both CBMS and non-CBMS courses, though there is divergence when higher numbers of upper division prerequisites are considered. Among the CBMS courses, 65% required two or fewer upper division prerequisites, while only 46% of non-CBMS courses required two or fewer.

**Table 7. Prerequisites for the capstone.**

| Course Name | All | All % | CBMS | CBMS % | Non-CBMS | non-CBMS % |
|---|---|---|---|---|---|---|
| Calculus | 35 | 97% | 22 | 96% | 13 | 100% |
| Linear Algebra | 31 | 86% | 18 | 78% | 13 | 100% |
| Discrete Mathematics | 6 | 17% | 4 | 17% | 2 | 15% |
| *Abstract Algebra | 14 | 39% | 9 | 39% | 5 | 38% |
| Euclidean Geometry | 13 | 36% | 6 | 26% | 7 | 54% |
| *Probability | 9 | 25% | 7 | 30% | 2 | 15% |
| *Real Analysis | 15 | 42% | 12 | 52% | 3 | 23% |
| *Calculus-Based Statistics | 8 | 22% | 7 | 30% | 1 | 8% |
| Other | 18 | 50% | 11 | 48% | 7 | 54% |
| Statistics with no Calculus prereq. | 15 | 42% | 7 | 30% | 8 | 62% |
| *Non-Euclidean Geometry | 19 | 53% | 12 | 52% | 7 | 54% |
| Combinatorics | 14 | 39% | 9 | 39% | 5 | 38% |
| n | 36 | | 23 | | 13 | |

* Upper-division courses

*Capstone course instruction and content.* Survey respondents were asked to describe the academic background of the instructor who has most often taught the course in the past five years. Table 8 summarizes the results. At least 14 out of 15 non-CBMS course instructors had backgrounds in mathematics; the fifteenth capstone course was reported to be conducted with individual instructors paired with students. One CBMS capstone course was co-taught by a mathematician and mathematics educator. Only four instructors, all of whom teach CBMS capstones, were reported to exclusively have a mathematics education background.

**Table 9. Instructor backgrounds.**

| Instructor Background | All | CBMS | non-CBMS |
|---|---|---|---|
| Mathematics | 35 | 21 | 14 |
| Mathematics Education | 14 | 12 | 2 |
| Both Math & Math Ed | 10 | 8 | 2 |
| n | 41 | 26 | 15 |

Note: Some capstones instructor backgrounds are not reflected in this table. There was one CBMS course instructor with a computer science background. One non-CBMS capstone course paired individual students and faculty members. Some instructors selected multiple backgrounds.

Survey respondents were also asked to comment on the level of instructor freedom in choosing the topics examined in the capstone course. Thirty-three of 41 capstone courses (80.5%) selected the following: "A lot - There are limited guidelines or recommendations for teaching this course, so instructors get to choose the materials they want to use." The rate was

consistent across CBMS and non-CBMS courses. Only one capstone course (CBMS) was reported to have no instructor freedom because a course coordinator chooses the materials. The other seven courses had some instructor freedom in the choice of topics; their chosen survey option was, "there are recommended curriculum materials, but the instructor is not required to use them." The survey also investigated instructor freedom in how the course was taught or structured. For this question, 100% of respondents reported yes to one of the following choices:

- Some - the department has recommendations for how the class is taught and expects instructors to use those recommendations as a guide, but not an imperative. (n=15)
- A lot - the department has no recommendations for how the course should be taught, so it is up to the instructor to decide how to teach the course. (n=25)

This level of instructor freedom was reflected in the variety of materials used for the courses. Among the 31 responses to questions about course materials, 18 different books were listed as course textbooks, 13 courses used various materials, and at least four used materials primarily developed internally. Among the many texts listed, only three were listed as a textbook for three or more capstone courses:

- *Mathematical connections: A capstone course*. Conway, J. (2010) – 3 courses
- *Mathematics for high school teachers: An advanced perspective.* Usiskin, Peressini, & Marchisotto, & Stanley (2002) – 7 courses
- *The mathematics that every secondary school math teacher needs to know.* Sultan & Artzt (2010) – 3 courses

Likewise, a wide variety of classroom technologies were used in the capstone courses. Of 39 respondents on this topic, only two reported to not use any technology in the course (both were non-CBMS courses). The most commonly used tools were Geometer's Sketchpad or Geogebra (15 and 6, respectively), graphing calculators (21), and Microsoft Excel (16). There was not a pronounced difference between CBMS and non-CBMS courses other than in the use of Excel; all 16 of the capstones that used Excel were CBMS courses.

Variety was detected in the content of the capstone courses. A survey question asked, "In the last semester that the course was taught, what mathematical or pedagogical topics were examined?" Table 10 shows counts for some categories of responses to this question. As compared with the non-CBMS courses, the CBMS courses included more secondary mathematics topics and pedagogical concerns. All of the non-CBMS courses addressed advanced mathematical topics.

**Table 10. Categories of topics covered.**

| Topic | All | CBMS | Non-CBMS |
|---|---|---|---|
| Deeper look at secondary mathematics | 11 | 11 | 0 |
| Advanced mathematical topics | 22 | 10 | 12 |
| History of mathematics | 7 | 4 | 3 |
| Pedagogical concerns | 6 | 6 | 0 |
| n | 33 | 21 | 12 |

In a typical semester or quarter, more than 60% of class time was spent on a combination of whole-class discussion, students working with partners or in small groups, and students working independently. The percentage of time devoted to each of these types of student work varied between CBMS and non-CBMS capstone courses. Notably, non-CBMS capstone courses devoted a larger amount of class time to students working independently (41% vs. 23% for CBMS capstones). Among all capstones, lectures accounted for 18% of class time

(16% for CBMS, 21% for non-CBMS capstones). The percentages of class time associated with different lesson implementations are summarized in Table 10.

**Table 10. In a semester/quarter, percentages of class time spent using various lesson designs/implementations.**

| Percentage of class time spent on: | All | CBMS | non-CBMS |
|---|---|---|---|
| Lecture | 18% | 16% | 21% |
| Whole-class discussion | 20% | 26% | 12% |
| Students working with partners or in small groups | 17% | 20% | 10% |
| Students working independently | 30% | 23% | 41% |
| Students exploring mathematical concepts using manipulatives | 3% | 4% | 1% |
| Students exploring mathematical concepts using technology | 4% | 5% | 1% |
| Student Presentations | 7% | 5% | 11% |
| Other | 1% | 0% | 3% |
| n | 41 | 26 | 15 |

Among the capstone courses surveyed, tests, presentations, and the reading of articles were reported as the most popular type of assignments. Each of these assignments, however, was more popular in CBMS capstone courses than in non-CBMS. Table 11 lists the percentages of respondents who use each of the listed assignments or activities.

**Table 11. Major assignments and in-class activities.**

| Assignments/Activities | All | CBMS | non-CBMS |
|---|---|---|---|
| Portfolios of course reflections | 20% | 23% | 13% |
| Plan and present lessons to the class | 39% | 54% | 13% |
| Plan and present lessons to secondary school mathematics classes | 10% | 15% | 0% |
| Analyze K - 12 textbooks and curriculum materials | 12% | 19% | 0% |
| Read and report on articles from practitioner journals | 34% | 38% | 27% |
| Field placements | 2% | 4% | 0% |
| Classroom Observations | 10% | 15% | 0% |
| Tests/quizzes | 32% | 38% | 20% |
| n | 41 | 26 | 15 |

## Discussion

In 2001, the CBMS recommended that pre-service high school mathematics teachers complete "a 6-hour capstone course connecting their college mathematics courses with high school mathematics" (p. 8). Ten years later, courses which align with this recommendation

seem not to be wide-spread. Only 26 out of the 73 institutions in our survey had at least one course which aligns with the CBMS recommendation. Furthermore, assuming that six hours of coursework would span more than one semester/quarter, only 7 of the 26 CBMS capstone courses in our sample likely satisfy this requirement. Looking beyond the CBMS recommendation, 16 additional institutions in our sample provide a capstone experience (not aligned with the CBMS) for this population of students.

The CBMS vs. non-CBMS distinction was determined by the stated purposes of the capstone course. A CBMS capstone course has the (not necessarily sole) purpose to connect college and high school mathematics, as recommended by the CBMS. Our survey, however, used a broader definition of capstone and included courses which fostered connections between college-level courses, provided exposure to additional mathematics content, and/or engaged students in communicating with or about mathematics. Indeed, most capstone courses reported in our survey addressed many of these and other goals and served multiple purposes. Our survey data indicates diversity across many characteristics of the courses which respondents identified as capstones.

Despite this diversity, some general features are shared by most capstone courses in our sample. These courses integrate group or individual student coursework during class time; on average, only 18% of time is devoted to lecture. The use of (not necessarily instructional) technology was popular among nearly all of the courses. All 41 capstone courses were completed by pre-service secondary mathematics teachers at the end of their undergraduate experience; however, only 12 of the 41 capstone courses were taken exclusively by pre-service secondary teachers. This lack of exclusivity may be connected to the CBMS observation that courses for future teachers may be difficult to implement in institutions that serve a small number of pre-service mathematics teachers (CBMS, 2012). Our survey, however, did not reveal this level of detail. In general, instructors reported a large amount of freedom in choosing the content and instructional style for their courses. This freedom is also reflected in the wide variety of assessment devices and resources used. It is possible that this is a byproduct of the capstone being a relatively new type of course. Indeed, a defining feature of the current state of capstone courses is the variety of implementations.

Within this variety, there are notable differences between CBMS and non-CBMS courses. As would be expected given the recentness of the CBMS recommendation, non-CBMS courses are typically older than the CBMS courses (10 vs. 7 years in median time since first offered). Furthermore, CBMS capstones are more likely to have been developed in consultation with national guidelines from mathematics and educational organizations. They are also more likely to be taught by someone with a mathematics education background. Though most (69%) capstone courses required upper division courses as pre-requisites, there were some differences in the type of courses required by CBMS courses, particularly in the areas of geometry and statistics and in the quantity of upper division prerequisites (more were required by non-CBMS capstones).

Given these differences between the two categories of capstones, along with their differences in purpose, it would be tempting to characterize the differences between CBMS and non-CBMS courses as being signs of different programmatic foci. Specifically, perhaps the CBMS courses are located in programs more focused on teacher preparation. However, there are also signs which indicate that this may not be the case. Notably, CBMS courses are more likely to include a calculus-based statistics course (instead of a lower-level statistics course) as a prerequisite and are less likely to have a Euclidean geometry prerequisite. That is, the prerequisite coursework in programs with CBMS capstones may be less amenable to making connections to high school content throughout the undergraduate program. Indeed, a capstone which focuses on high school connections may be more of a necessity in

departments with prerequisite coursework which does not support this. The nature of an individual capstone course may indicate little about the program which houses it.

In February 2012, the CBMS released a draft of an update to their 2001 recommendations for the mathematics education of teachers (CBMS, 2012). The new document does not include the word "capstone." Instead, the CBMS recommends that pre-service secondary mathematics teachers complete the equivalent of a mathematics major "that includes three courses with a primary focus on high school mathematics from an advanced viewpoint" (p. 7). Absent from the recommendations is advice on when these courses should be taken; in particular, there is no recommendation that these courses are intended as a capstone at the end of an undergraduate program. It has been barely more than a decade since the CBMS recommended the capstone and, though the recommendation was not renewed in the 2012 draft, the CBMS has strengthened the recommendation for pre-service teachers to interact with high school mathematics content at a deeper level. Though our study was more widely focused than trying to measure the impact of the CBMS recommendation, the survey results give some indication of how the new recommendations may be interpreted and implemented. More generally, though, our survey uncovered and described much about the status of capstone courses in the preparation of secondary mathematics teachers.

## References


Artzt, A., Sultan, A., Curcio, F. R., & Gurl, T. (2011). A capstone mathematics course for prospective secondary mathematics teachers. *Journal of Mathematics Teacher Education*, Online First, June 14, 2011.

Carnegie Classifications. (2011). *Carnegie Foundation for the Advancement of Teaching*. Retrieved from http://classifications.carnegiefoundation.org/resources/

Conference Board of the Mathematical Sciences (CBMS). (2001). *The mathematical education of teachers.* Providence, RI: American Mathematical Society.

Conference Board of the Mathematical Sciences (CBMS). (2012). *The mathematical education of teachers II: Draft for public discussion, February 9, 2012.* Retrieved from http://www.cbmsweb.org/MET2/MET2Draft.pdf

Conway, J. B. (2010). *Mathematical connections: A capstone course*. Providence, RI: American Mathematical Society.

Hill, R., & Senk, S. (2004). A capstone course for prospective high school mathematics teachers. *Mathematicians and Education Reform Newsletter*, *16*(2), 8-11.

Hodgson, B. (2001). The mathematical education of school teachers: Role and responsibilities of university mathematicians. In D. A. Holton (Ed.) *The teaching and learning of mathematics at the university level: An ICMI study* (pp. 501-518). Boston, MA: Kluwer Academic Publishers.

Klein, F. (1932). *Elementary mathematics from an advanced standpoint: Arithmetic, algebra, analysis.* New York: Macmillan.

Loe, M., & Rezak, H. (2006). Creating and implementing a capstone course for future secondary mathematics teachers. In K. Lynch-Davis and R. L. Rider (Eds.) *The work of mathematics teacher dducators: Continuing the conversation Monograph Series Volume 3*(pp. 45-62). San Diego, CA: AMTE.

Monk, D. H. (1994). Subject area preparation of secondary mathematics and science teachers and student achievement. *Economics of education review*, *13*(2), 125-145.

Shoaf, M. M. (2000). A capstone course for pre-service secondary mathematics teachers. *International Journal of Mathematical Education in Science and Technology*, *31*(1), 151-160.

Usiskin, Z., Peressini, A. L., Marchisotto, E., & Stanley, D. (2002). *Mathematics for high school teachers: An advanced perspective* (1st ed.). Upper Saddle River, NJ: Prentice Hall.

Van Voorst, C. (2004). Capstone mathematics course for teachers. *Issues in the Undergraduate Mathematics Preparation of School Teachers: The Journal*, *4*, 1-11.

Sultan, A., & Artzt, A. F. (2011). *The mathematics that every secondary school math teacher needs to know*. New York, NY: Routledge.

## Appendix A: Survey Questions

P1. What is the name of your institution? (This will only be used internally and will be removed from the data during analysis.)

P2. Capstone Course Definition: For the purpose of this survey, we define a capstone course for pre-service secondary mathematics teachers in the following way: A Capstone course is a content course taken at the conclusion of a program of study for pre-service secondary mathematics teachers that satisfies at least one of the following criteria for a capstone course (Loe and Rezac, 2006): (1) Provide bridges among upper-level mathematics courses, especially real analysis, abstract algebra, and geometry; (2) Provide preservice teachers an opportunity to explore connections to the high school curriculum so that they have a better understanding of the mathematics they will teach; (3) Provide preservice teachers with additional exposure to areas of mathematics in which they may be deficient; (4) Provide preservice teachers experiences with research and writing in mathematics and oral presentations to their peers and instructors. Please exclude from this definition a course that is specifically related to mathematics teaching methods (i.e., a "methods" course). Based on this definition, does your department offer at least one capstone course to pre-service secondary mathematics teachers?

Q1. What is the name of the course(s)?

Q2. How many total credit hours are offered for the course(s)?

Q3. How are the total credit hours divided among different forms of the class, such as some hours of lecture and some hours of lab/workshop or practicum? Please fill in the number of hours for each below:
(a) Lecture, (b) Workshop/Lab/Activity Hours, (c) Practicum Hours, (d) Other

Q4. How long is the duration of the course (i.e., the number of quarters, semesters, or years)?

Q5. How is this course described to students? (If your institution has an on-line course catalog, it would be acceptable to copy and paste the description here.)

Q6. How long has this / course been offered at your institution? Time (in years):

Q7. What purpose does the capstone course serve in your program of study? Please check all that apply:
(a) To provide bridges between upper-level mathematics courses, especially real analysis, abstract algebra, probability/statistics, and geometry, (b) To provide pre-service teachers with an opportunity to explore connections between college mathematics and secondary school mathematics, (c) To provide pre-service teachers with additional exposure to areas of mathematics in which they may be deficient, (d) To provide pre-service teachers experiences with research and writing in mathematics and with making oral presentations to their peers and instructors, (e) To provide pre-service teachers with the opportunity to learn pedagogical principles for teaching secondary mathematics, (f) To provide pre-service teachers with opportunities to become familiar with technology for teaching, (g) Other (please describe)

Q8. What outcomes/goals do you have for students enrolled in your capstone course? Please check all that apply:

(a) Students are knowledgeable about the university mathematics content addressed in the course, (b) Students take an in-depth look at some mathematical topics which are particularly important in secondary mathematics, (c) Students know how to use a variety of teaching strategies when teaching mathematics, (d) Students can (effectively) integrate technology into their future classrooms, (e) Students connect appropriate college mathematics content to high school mathematics content and pedagogy, (f) Students become aware of current topics and issues in secondary school mathematics, (g) Students develop a deeper appreciation of mathematics, (h) Students develop a personal philosophy to support the teaching of secondary mathematics, (i) Other

Q9. In a typical quarter or semester, what percentage of class time is spent engaging in the following activities?

(a) Lecture, (b) Whole-class discussion, (c) Students working with partners or in small groups, (d) Students working independently, (e) Students exploring mathematical concepts using manipulatives, (f) Students exploring mathematical concepts using technology, (g) Other, (h) Other-TEXT

Q10. What are some major assignments or in-class activities that are required of students in the capstone course offered at your university? Please check all that apply:

(a) Portfolios of course reflections, (b) Plan and present lessons to the class, (c) Plan and present lessons to secondary school mathematics classes, (d) Analyze K - 12 textbooks and curriculum materials, (e) Read and report on articles from practitioner journals, (f) Field placements, (g) Classroom Observations, (h) Tests/quizzes, (i) Other

Q11. What are the mathematics prerequisites for the capstone course at your university? Please check all that apply:

(a) Calculus, (b) Linear Algebra, (c) Combinatorics, (d) Probability, (e) Calculus-Based Statistics, (f) Statistics with no prerequisite in Calculus, (g) Euclidean Geometry, (h) Non-Euclidean Geometry, (i) Abstract Algebra, (j) Real Analysis, (k) Discrete Mathematics, (l) Other, (m) There are no prerequisites for the course

Q12A. Is this a required course for certain majors or degree options?

Q12B. To whom is this course available? Please check all that apply:

(a) Alternate licensure students post-baccalaureate, (b) Graduate students, (c) Undergraduate math majors, (d) Undergraduate math majors pursuing teaching licensure, (e) Undergraduate mathematics education majors pursuing teaching licensure, (f) Undergraduate math minors, (g) Undergraduate math minors pursuing licensure, (h) Other

Q13. In the past five years, how would you describe the academic background of the instructor who has most often taught your capstone course? Please check all that apply:

(a) Mathematics, (b) Mathematics Education, (c) Education, (d) Education Administration, (e) Curriculum and Instruction, (f) Other (please describe)

Q14. What titles of textbooks have been used by faculty or students in teaching the capstone course in the last five years? Please check all that apply:

(a) Bremigan, E., Bremigan, R. and Lorch, J. (2011). Mathematics for secondary school teachers. MAA., (b) Cooney, T.J., Brown, S.I., Dossey, J.A., & Wittmann, E.Ch. (1996). Mathematics, pedagogy, and secondary teacher education. Portsmouth, NH: Heinemann., (c) Conway, J. (2010). Mathematical connections: A capstone course. Providence, RI: AMS., (d) Cuoco, A. (2005). Mathematical connections: A companion for teachers and others. Newton, MA: Educational Development Center., (e) Sultan, A., & Artzt, A.F. (2010). The mathematics that every secondary school math teacher needs to know. Hoboken, NJ: Taylor & Francis., (f) Usiskin, Z., Stanley, R., Peressin, A., & Marchisotto, E. (2003). Mathematics for high school teachers: An advanced perspective. Needham, MA: Prentice Hall., (g) Other (ISBN would suffice)

Q15. Has your department or have instructors of this course developed any supplemental materials for this course? Describe any additional materials have you developed or incorporated in this course

Q16. In the last semester that the course was taught, what mathematical or pedagogical topics were examined? If the capstone course changes from semester to semester, please indicate this along with a range of topics that you feel are representative of those included.

Q17. How much instructor freedom is permitted in choosing the topics examined in the capstone course?

(a) None - the course has a coordinator that chooses all of the materials/textbook, etc., (b) None - the course was developed by a curriculum committee., (c) Some - there are recommended curriculum materials, but the instructor is not required to use them., (d) A lot - There are limited guidelines or recommendations for teaching this course, so instructors get to choose the materials they want to use., (e) Please comment as needed

Q18. How much instructor freedom is permitted for how the class is taught/structured?

(a) None - the department has recommendations for how the class is taught and expects instructors to closely follow those recommendations., (b) Some - the department has recommendations for how the class is taught and expects instructors to use those recommendations as a guide, but not an imperative., (c) A lot - the department has no recommendations for how the course should be taught, so it is up to the instructor to decide how to teach the course., (d) Please comment as needed

Q19. What resources were used to develop this course? Please check all that apply:

(a) State guidelines, (b) National guidelines, (c) Common Core State Standards, (d) National Council of Teachers of Mathematics, (e) Conference Board of the Mathematical Sciences, (f) Mathematics Association of America, (g) National Mathematics Advisory Board Recommendations, (h) Collaboration with other departments on campus (please name those departments), (j) Collaboration with other universities, (k) Other (please describe)

Q20. Check any classroom technology used in this course that these future teachers may eventually use in their classrooms?

(a) Geometer's Sketchpad, (b) Geogebra, (c) Graphing Calculators, (d) Excel, (e) Fathom, (f) TinkerPlots, (g) Handheld devices, (h) Cell phones/applications, (i) Wikis/ Social Networking Tools, (j) Other, (k) No technology is used

Q21. Have you done any follow-up on the usefulness/success of this course? You will not be asked to describe the outcomes. Check all that apply:

(a) End of course teacher evaluation, (b) Exit interviews with students, (c) Feedback from student teachers, (d) Longitudinal research on this course, (e) Anecdotal evidence on the effectiveness of the course, (f) Other:, (h) No follow-up data has been collected

Q22. If available, please take a moment to upload a recent syllabus used in your capstone course. Microsoft Word or PDF formats are all fine (.doc, .docx, .pdf).