

Preparing Middle School Mathematics Teachers

COMET Subcommittee on Middle School Teacher Preparation Curriculum

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Introduction. There has been increasing scrutiny placed on the performance of K-12 mathematics teachers, and on the efforts of those in higher education who prepare and support them in their work. Of particular concern is the preparation and professional development of those who teach mathematics to the students in the middle grades (considered here as grades 6, 7 and 8). Unlike preparation of high school and elementary school teachers, there is much less consensus on what constitutes adequate preparation for teaching mathematics to students in the middle grades. While 46 states have a license or certificate specific to teaching middle school mathematics (all but two of which include grade 5) [1, p.39]¹, our committee's survey of teacher preparation programs revealed a surprisingly low number of institutions who have programs dedicated to the preparation of middle school mathematics teachers. Some institutions absorb the middle-school mathematics preparation into their high school preparation program. Other institutions adapt their multiple-subject teacher preparation program by having pre-service teachers take additional mathematics courses to qualify for teaching mathematics in the middle grades. Programs designed specifically to prepare pre-service teachers to teach middle school mathematics are comparatively rare.

The Mathematical Education of Teachers II report (MET II) from the Conference Board of the Mathematical Sciences [1] (<http://cbmsweb.org/MET2/index.htm>) calls for institutions of higher learning to offer and support programs designed specifically to prepare undergraduates to teach mathematics in grades 5 through 8. This report presents recommendations for a program for preparing middle school mathematics teachers that builds on the MET II report, while providing guidance for smaller programs to create innovative means by which to enact as many of the recommendations as possible. The caution that a traditional mathematics major does not provide suitable preparation for teaching mathematics goes hand in hand with the concern that a multiple credential does not adequately prepare teachers to teach middle school mathematics, so all departments who take their teacher preparation seriously are encouraged to offer a pre-service middle school program.

¹ See also:

<http://www.amle.org/AboutAMLE/ProfessionalPreparation/Certification-LicensurebyState.aspx>

Middle school students taking mathematics truly find themselves in the middle: the representation-based understandings of arithmetic and the concepts and procedures of elementary school give way to the beginnings of algebra and more formal arguments, while the more rigorous use of geometry and functions to explore the concepts of trigonometry, statistics, and calculus lurks on the horizon. To that end, teachers of middle school mathematics need to be prepared to take their students from elementary school mathematics to high school mathematics, and so need a dedicated education that gives them the tools they need to guide their students through that transition.

Changing Expectations. As reported in the MET II document, the expectations for middle school students in their mathematics classes have increased over the years. The Common Core State Standards (CCSS) will further broaden and deepen the material middle school students will be expected to master in their mathematics classes.

Most notably, the role of statistics and probability in middle school mathematics standards has become much more prominent. The CCSS calls for middle school students to be able to compare distributions of data through graphical and numerical summaries, calculate probabilities both theoretically and experimentally, work with bivariate data, and come to terms with sampling variability, skills that aren't assumed in today's introductory college statistics courses.

These changing expectations for middle school students makes it imperative that pre-service middle school teachers receive adequate, appropriate, and dedicated training in order to enable their future students to meet these growing demands on their abilities. Additionally, the changes in the curriculum mean that practicing middle school teachers will need to learn new material. Mathematics departments can meet this need by enrolling those teachers in some of the same courses taken by pre-service teachers, enriching the classroom experience for the inexperienced pre-service teachers and addressing concerns about undersubscribed courses.

Two alternative approaches. Currently, the majority of middle school teachers have received their credentials either by completing a program designed for teaching high school mathematics, or by tailoring or supplementing a multiple-subject credential originally designed for elementary school teachers. Given the special needs of middle school students, and the increased demands on their abilities and skills, neither of these approaches directly prepares someone to teach middle school mathematics.

A teacher preparation program for high school mathematics teachers is generally not adequate for pre-service teachers who are planning to teach middle school mathematics. The mathematics topics taught in middle schools are substantially different from those taught in high schools, and the needs and mathematical sophistication of the students are substantially different. In addition, most high-school mathematics teacher preparation programs rely on courses designed for the general mathematics major, instead of providing specialized content courses that prepare pre-service teachers to teach high-school mathematics, and will be even less appropriate to prepare pre-service teachers to teach middle school

mathematics.

The alternate approach of customizing or supplementing a program designed as a part of a multiple-subject credential also does not adequately prepare pre-service teachers to teach mathematics at the middle school level. Middle school students are more sophisticated, and will be expected to demonstrate more integrative and thorough work in their mathematics classes than their elementary school counterparts, not to just simply know more concepts. Middle school teachers should be prepared with more deliberate intent than simply adding content courses on top of a multiple-subject credential. The increasingly deep expectations placed on middle school students regarding their mathematical education suggests that their teachers receive more extensive training in the subject than an adapted multiple-subject program would allow.

This report agrees with the recommendation in MET II, which states that middle school teachers should be familiar with the mathematics that students will have seen through Grade 5, and be familiar with the mathematics students will see as they move into high school. Neither an augmented multiple-subject program, nor a high-school credential program, on its own, provides sufficient preparation for a middle-school mathematics teacher. Middle grade teachers need to specialize in mathematics, and they need focused opportunities to work deeply with the mathematics they will be expected to teach.

Three different models. The two models of preparation described above--- modifying the preparation of a high school mathematics teacher by adding or substituting pedagogy courses in lower level mathematics, and increasing the mathematical content in the preparation of an elementary school teacher by adding upper level mathematics courses--- can provide manageable, if less desirable, approaches to middle school teacher preparation, depending on the modifications. For instance, this report will strongly recommended that either model include at least one course dedicated to mathematics in the middle school curriculum.

But this report favors a third model. In this model, a middle school teacher would enroll in a program that offers numerous courses specifically designed for middle school teachers, along with additional coursework in mathematics. This approach is also recommended in the MET II report's middle school chapter (<http://cbmsweb.org/MET2/index.htm>), and we repeat and support many of their recommendations here. After describing this dedicated model, we offer suggestions for the modifications in the other models of middle school teacher preparation.

Model I. Proposed curriculum for the Dedicated Model

MET II calls for a dedicated program of 15 semester-hours of coursework specifically designed for pre-service middle school teachers in addition to 9 semester-hours of additional work in mathematics. We offer a similar, slightly longer, recommendation, in terms of semesters rather than course units. Institutions on quarters or trimesters can adjust the recommended times

accordingly. For more specifics on the recommended courses beyond the comments included here, see the MET II report.

A. Courses designed specifically to meet the needs of future Middle School Teachers (5 semester-long courses)

1. Numbers and operations 1
2. Number and operations 2 (ratios, proportional relationships, co-varying quantities, invariant relationships, early algebraic reasoning)
3. Algebra and number theory
4. Geometry and measurement
5. Statistics and probability

Comments. The MET II report recommends 6 semester-hours in “number and operations” and 3 semester-hours in “algebra and number theory.” Those courses are reorganized here into two semester long courses, *Numbers and number theory* and *Algebra and operations*, to reflect a semester system, and to give a little more description to the current practice in a few programs where these courses have titles along the lines of *Foundations of Middle School Mathematics* and are taught over two semesters. In any case, this model calls for at least a full year devoted to the foundations of middle school mathematics, involving the real number system, arithmetic operations, equations, proportional relationships, and divisibility.

An algebra and number theory course would not be the typical College Algebra course taught at most universities. Instead, it would focus on the algebra taught at the middle school level. One possibility would have students focusing on connections between the use of manipulatives and the underlying mathematics of those uses. The specific topics covered in the class may involve operations involving positive and negative integers, solving linear equations, and solving quadratic equations using these manipulatives. This would not only strengthen the content knowledge of the pre-service teachers, but would also allow exposure to some pedagogical techniques.

Geometry and measurement was the most common course included in a survey of existing programs conducted by the members of this working group. Given the prominence of geometry in the middle school curriculum, middle school mathematics teachers need an opportunity to work deeply with the geometry topics they will be expected to teach, with particular attention given to *teaching* geometric reasoning.

The CCSS call for a major increase in *Statistics* instruction in the middle schools, and this model adopts the recommendations of the MET II report by including two statistics courses. The second of the two would be intended specifically for middle school teachers, to provide them with an experience of learning statistics and probability through active learning and technology, and would carry the standard introductory statistics course as a prerequisite. The two-course sequence allows for an immersive, focused experience in the second course designed specifically for prospective middle school teachers.

The justification for two statistics courses is that, because so little statistics appeared in the pre-Common Core high school curriculum, future teachers need to learn the Common Core statistics material well in the first college statistics course, and then take a second college statistics course that builds on the Common Core material. Two possible course syllabi for this second course suggested by statistics educators are in the statistics section of this Guide, and in the forthcoming Statistical Education of Teachers report. The MET II high school chapter has recommendations for a single lower-division course for future teachers that can also serve as an introductory statistics course for other majors.

For all four of these courses, the recommendation is that they not be courses designed for general mathematics majors, or for pre-service high school teachers, or as part of the multiple subject credential, but that they address the specific needs of the prospective middle school teachers.

B. Supporting coursework in mathematics (3 semester-long courses)

1. Introductory Probability and Statistics

Two from:

2. Discrete mathematics
3. Calculus or Calculus Concepts
4. Problem Solving
5. History of Mathematics

The introductory statistics course will be a necessary prerequisite for the type of middle-school specific course described in the previous section. The goals of the other courses would be to provide pre-service teachers with tools and further skills to expand on the mathematical topics they will be teaching in their classrooms, to place those topics in historical or disciplinary context, and to provide experience with the mathematics their students will move on to in high school. The list of courses reflects their increased inclusion in the middle school curriculum, their ability to illustrate the use of middle school mathematics in more advanced contexts, and the opportunities they offer students to develop an increased facility with mathematics.

These classes may be combined, either intentionally or fortuitously, at several institutions. For example, one school's problem solving course might be taught using topics in discrete mathematics; at another, there may be a History of Calculus class, which would make them more attractive choices for a prospective middle school teachers looking for two appropriate classes of supporting coursework.

Practical concerns. The recommended program contains 8 semester-long courses, which means it does not quite constitute a major at many institutions, so there is a practical concern about finding a home for this program. Supplemented with some upper division coursework, the program could serve as one track in a mathematics major. In schools with established education departments, these courses, together with supporting coursework in pedagogy and classroom methods, could serve as a major or credentialing program. It would be difficult for a student to add these

courses on top of an existing major, and this report acknowledges the difficulties involved in working these courses into a student's course of study, but the need for outstanding middle school mathematics teachers and the advantages these courses offer outweigh the difficulties.

This report also acknowledges that it is currently a time of limited resources for many institutions of higher education. Even if desired, it may not be possible for an institution to start up a new teacher preparation from scratch if one isn't already in place. Indeed, it is hoped that this report might serve as support for *protecting* middle school teacher preparation programs that have already been established, but may be under pressure. However, for institutions with established programs in the preparation of high school teachers, or for institutions with established multiple-subject credential programs, we offer alternate models that build on these established programs. Although this report favors Model I, it acknowledges that there are advantages to these other models, not the least of which is increased practicality and reduced investment in order to get them started.

In both of the alternative models, it should be emphasized that the programs should have a component specifically designed for middle school mathematics teachers, and that pursuing the middle school alternative should not be viewed as somehow inferior to the established path through the programs. The preparation of middle school teachers should not be viewed as an easier path through the education track of a mathematics major, or as a way to avoid some of the work in a multiple-subject credential. In either alternative, the middle school preparation program should be viewed as equally valid as the established one off of which it is based. Finally, it may be the case at an institution with established programs in both high school and elementary school teacher preparation, that the alterations suggested in Models II and III might lead to a program similar to Model I.

Model II. Proposed Alterations to a High School Preparation Program

Refer to the MET II high school chapter and to the Curriculum Guide for a Professional Program to Prepare High School Teachers for recommendations on curriculum for a high school preparation program. We discuss ways in which expected discrepancies between an established high school program and Model I might be expeditiously addressed with a minimal compromise of the needs of a prospective middle school teacher.

Required Courses (2 semesters)

1. Numbers and number theory
2. Algebra and operations

Middle school teachers need a substantial amount of time to work specifically with the concepts they will be teaching, at a deep level, and they may not encounter these topics in a program where the high school preparation curriculum relies heavily on a standard mathematics major.

Adapted Courses

3. Geometry. Most high school preparation programs mandate a course in geometry,

and, as long as such a course is designed specifically for pre-service teachers, it could serve middle school teachers well. Indeed, if an institution's geometry course is not meant primarily for pre-service teachers, establishing a middle school teaching track in the mathematics major might provide an opportunity to redesign the course. If the current high school preparation program does not include a course in geometry, one should be added for middle school teachers, given the preeminence of the subject in the middle school curriculum.

4. Statistics and probability. The MET II report recommends a two-course sequence in statistics for pre-service high school teachers, and this report does for middle school teachers. To that end, a high school preparation program should have a substantial statistics component. If it does not, one should be added for both middle and high school teacher preparation programs. Otherwise, as long as the pre-service teachers experience active learning, experimental design and data collection, and appropriate use of technology, this one or, ideally, two-course statistics component could serve both populations of pre-service teachers.

The additional courses in mathematics recommended in Model I should still be available through a mathematics department, and should be included as part of a prescribed path through the major, if similar courses aren't already required for the high school preparation program.

Model III. Proposed Alterations to a Multiple Subject Credential Program

Refer to the MET II elementary school chapter for recommendations on curriculum for a multiple-subject credential program. We will discuss ways in which possible discrepancies between an established multiple-subject credential program and Model I might be expeditiously addresses with a minimal compromise of the needs of a prospective middle school teacher.

Most multiple-subject credential programs are not housed in departments of mathematics, but rather in departments (or schools) of education. Our recommendations are intended to insure that pre-service teachers of elementary or middle school mathematics get the opportunity to work at a deep level with the mathematical content they will be covering in the classroom. This need is particularly acute for prospective middle school teachers, as the mathematical content in grades 6, 7, and 8 has become both broader and deeper in the CCSS.

Required Courses (3 semesters)

1. Algebra and operations
2. Geometry and measurement
3. Statistics and probability

Multiple-subject credential programs usually cover numbers and number systems in their mathematical content courses, and this may be sufficient for pre-service middle school teachers (see *Adapted Courses* in this model below), but they generally will not provide enough work with equations and algebraic manipulations, so this report recommends an additional mathematical content course to address this discrepancy. Further, since geometry plays a large and pivotal role in the middle school curriculum, and at a relatively deep level, particularly in terms of proof and

mathematical argument, we recommend a geometry course designed for middle school teachers, beyond or in place of any geometrical content in the multiple-subject program.

Finally, it remains desirable that pre-service middle school teachers receive a two-course sequence in statistics and probability. Given that most multiple-subject credential pre-service teachers acquire experience working with hands-on activities, active learning strategies, and basic statistical concepts, this report recommends that middle school teachers take an introductory statistics course, preferably one designed to emphasize conceptual understanding of the tools and test of elementary statistics, before they take the statistical component of the multiple-subject preparation, so that they can apply the techniques learned in the second course to more advanced statistical concepts. If possible, a statistics course for prospective teachers at all levels could be designed and incorporated into both the multiple-subject and middle school preparation programs.

Adapted Courses

4. Number and number theory. Any multiple-subject credential program should give its pre-service teachers experience working with the real numbers; understanding of basic differences among number systems (natural numbers, integers, rational numbers, and real numbers); and ways of calculating the result of arithmetical operations, including different algorithms for addition, subtraction, multiplication, and division; and patterns in divisibility. It is expected that prospective middle school teachers would take that component of the program. The mathematical content should be increased, to go deeper and broader for pre-service middle school teachers, but this increase in emphasis on mathematical content would also serve multiple-subject credential pre-service teachers well. Adapting an existing multiple-subject credential program for middle school teachers could provide an opportunity to increase the mathematical content knowledge for all prospective teachers, including at the K-5 level.

The additional courses 2 through 5 in mathematics recommended in Model I should still be available through a mathematics department, and may be collected into a minor or field of emphasis in the mathematics department. This report recommends the inclusion of the extra mathematical content in whatever official designation the middle school preparation program receives.

Further Comments.

Other Suggested Courses. As useful choices for electives, or in order to include enough credits to warrant listing as a full major or credential program, this report recommends any of these courses for a prospective middle school mathematics teacher.

1. Introduction to computer science
2. A science course that exposes undergraduates to the quantitative aspects in scientific fields
3. Economics

These courses provide context for the mathematics taught in middle school mathematics classrooms, and can serve as sources for projects and applications of the mathematical content. In addition, an experience in computer science can provide tools for a prospective teacher to bring technology into the classroom in different contexts, such as running simulations, organizing data, or producing graphical representations. Finally, a teacher who is accomplished in the use of technology can demonstrate a variety of ways to use computers as problem-solving tools.

Comment on technology. This report echoes the Professional Program for High School Teachers Curriculum Guide in recommending that technology should be an integrated component throughout the preparation of middle school teachers, and not a standalone component, for example, by being taught through a course on Instructional Technology. The classroom experience of pre-service middle school teachers should provide a model for the kind of instruction we hope they will use in their own classrooms, and a preparation program devoid of integrated use of technology does not properly model how they should instruct their future middle school students.

Beyond the four year degree. The MET II report has an extensive discussion of professional development for middle and high school teachers after they have entered their classrooms. We endorse its recommendations, and call particular attention to the call for middle school teachers to work, not just on their own professional development and with other teachers of middle school mathematics, but also to work closely with high school and elementary school teachers of mathematics, as they work to continually improve the process by which they guide their students from elementary mathematics to high school mathematics.

References.

1. Conference Board of the Mathematical Sciences, *The Mathematical Education of Teachers, II*. American Mathematical Society and Mathematical Association of America, 2012. <http://cbmsweb.org/MET2/index.htm>
2. National Governors Association Center for Best Practices, Council of Chief State School Officers, *Common Core State Standards for Mathematics*. National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010.