AN ADVANCED MATHEMATICS PROGRAM FOR MIDDLE SCHOOL TEACHERS

D. CAROTHERS
Dept. of Mathematics, James Madison University
Harrisonburg, VA 22807
carothdc@jmu.edu

Abstract

The Conference Board of the Mathematical Sciences (CBMS), National Council of Teachers of Mathematics, and other organizations recommend twenty-one credits of mathematics coursework for prospective middle school teachers, beginning with a foundation based on mathematics for the elementary school curriculum, and followed by advanced courses directly addressing middle school mathematics. Three simultaneous factors—the emergence of the Interdisciplinary Liberal Studies Program at James Madison University, the release of CBMS guidelines, and a statewide focus on a critical shortage of qualified middle school teachers—provided an immediate audience for new upper-division courses built around the guidelines in probability/statistics, algebra, geometry, and calculus/analysis. We will discuss our experience with course planning and adaptation of other programs.

In the late 1990s, James Madison University (JMU) committed to developing a new Interdisciplinary Liberal Studies (IDLS) major designed for elementary and middle school teachers, and several groups around the University considered how best to accomplish the goals of the program using new or existing courses. This was fortunate timing for the Department of Mathematics and Statistics. The larger mathematical community was anticipating the release of the Conference Board of the Mathematical Sciences (CBMS) report on the *Mathematical Education of Teachers* (hereafter referred to as *MET*) [1]. In Virginia, there was increasing attention and concern about the preparation of middle school teachers [2]. A severe shortage of qualified middle school teachers in Virginia and elsewhere was well documented.

The University had an existing two-course sequence, including the usual topics in mathematics for elementary teachers courses, although previously the sequence had not been required, and prospective teachers could fill their three-credit, university-wide mathematics requirement by taking any one of several different courses. The Department of Mathematics and Statistics saw the new requirements for nine credits of mathematics for all students in the IDLS major, as well as a need for twelve credits of additional coursework for those electing a mathematics/science concentration, as an opportunity to develop a model program for middle

school teachers, thereby rejecting the option of making do with existing classes less directly tied to the needs of future teachers.

The Department was able to obtain a modest National Science Foundation grant (through DUE-CCLI) for an Adaptation and Implementation project, beginning in 1999. The primary goal was to demonstrate the feasibility of adapting previous NSF-supported work using limited resources to build a model middle school program.

Calls for new programs designed for middle school mathematics teachers predate *MET*. Notably, the Mathematical Association of America (MAA) in *A Call for Change* and the National Council of Teachers of Mathematics (NCTM) in *Professional Standards for Teaching Mathematics* describe twenty-one credit hours of university mathematics for future teachers: nine credits that included mathematics for elementary school teachers as a prerequisite to twelve additional credits for the middle school teachers on advanced topics, such as concepts of calculus, algebra, geometry, and probability and statistics [3,4]. In particular, *A Call for Change* suggests that, "If the recommended *Standards* cannot be met satisfactorily within currently offered undergraduate courses, then special courses should be developed that provide the proper focus and breadth of experience for these teachers." [5]

Our departmental curriculum approval process would require that the new courses be sufficiently sophisticated to merit upper-division numbering, as required by the IDLS program. Building new courses around the MAA/NCTM recommendations made this more feasible, since the advanced courses would be able to build on the lower-division coursework. For example, IDLS students would be studying the mathematics of change in a course whose prerequisites had involved significant problem solving and the properties of real numbers, rather than being diverted into a calculus course designed primarily for first-year science or business majors.

By 1999, programs specifically designed for middle school mathematics teachers remained rare, and nearly all programs were built around coursework originally designed for mathematics majors or service courses for other disciplines. To find an adaptable program, JMU turned to the large mathematics education group at Illinois State University (ISU), where a successful complete major program in mathematics for middle school teachers, consisting of many more than twenty-one credits, had existed for some years. At ISU, we found courses

designed for an audience similar to ours, capable students who, though not attracted to the traditional mathematics major, possess an interest in mathematics and motivation to develop the profound understanding of mathematics needed by effective teachers. Our challenge was to capture the essential mathematics for middle school preparation in the more limited number of credit hours allotted to the IDLS mathematics program, the same number of credits recommended by NCTM, et al.

In addition to providing small stipends for JMU course developers, our NSF funding enabled us to send a team to ISU to meet with course faculty, to involve a group of experienced local middle school teachers in the development of the courses, and to encourage further involvement in teacher-oriented professional meetings.

Our project eventually developed five courses, a problem solving class to bring the required lower division mathematics courses up to nine credits, and four additional classes for the IDLS mathematics/science concentration:

- *Math 304 - Principles of Algebra*
- *Math 305 - Principles of Geometry*
- *Math 306 - Principles of Analysis*
- *Math 307 - Principles of Probability and Statistics*

It is difficult to give a very brief summary of the experiences of those developing these courses, so we will restrict it to just a few of the highlights common to all.

The fact that about 30% of IDLS students elect the mathematics/science concentration suggests that this is not necessarily a mathematically "elite" group. Nevertheless, instructors have been impressed by the ability of the students to work on topics in advanced mathematics and, in at least some instances, they have not been so much different from upper-division mathematics majors. At this point in their education, students in this career path are usually highly motivated. As one might predict, it is a particularly difficult but important task to convince students of the relevance of studying a particular body of mathematical knowledge as preparation for middle school education. Continual reference to NCTM and CBMS guidelines can be somewhat helpful, and the input we had from participating middle school teachers was

especially useful, but this promises to be an area that will need continual attention through the coming semesters.

Anyone reviewing the professional society guidelines would be able to make reasonable guesses about the content of the algebra and geometry classes. However, there are certainly choices to be made, as well as analysis about the appropriate depth of the mathematical content to satisfy the upper-division designation.

There is a somewhat greater emphasis on probability modeling in our course when compared to a standard introductory probability and statistics course, as might be inferred from the content of middle school mathematics and the professional guidelines. The analysis course is perhaps the greatest departure from coursework elsewhere in the curriculum. Both *MET* and NCTM recommend some exposure to the ideas of calculus, but a standard mainstream or service calculus class would not build on students' knowledge of the number system from lower-division classes. In addition, although there is some emphasis on discrete mathematics in the algebra course, further exposure to discrete topics seemed to be appropriate. Thus, the analysis course begins with a study of sequences, continues to consideration of difference equations (with appropriate modeling experiences), and turns at the end to a brief introduction to the fundamental notions of (continuous) calculus.

When the *MET* guidelines were released partway through our NSF project, we were pleased to see that our development plans were quite consistent with the *MET* recommendations. We believe that the time has come for many more mathematics departments to invest effort in comprehensive middle school preparation programs. Materials for these courses are increasingly available, greatly easing problems with course development. Our project did not have the goal of producing materials for a mass market, but there are certainly many things that mathematicians beginning a new program can learn from our course content by visiting our website [5]. Several other projects involving individual courses or comprehensive programs; for example, the course development done at Virginia Commonwealth University (VCU), are also useful. An especially promising resource is a large NSF-funded project at the University of Missouri that began in 2001. Missouri's *(CM)^2 Connecting Middle School and College Mathematics* is developing four courses roughly equivalent to those at JMU, but the project will have significantly greater funding

that should enable them to produce usable materials that can be adapted to other institutions with considerably less effort [6].

Robert Watson, formerly director of NSF-DUE, has written, "Addressing this new audience could rejuvenate many departments, perform a much needed national service, and—as an added bonus—quite possibly recruit more students to major in the sciences." [7] Part of this comment may seem like an overstatement for departments stressed by too many demands and not enough resources. Nevertheless, while many mathematics and science departments have seen huge increases in freshman level and service courses, upper-division advanced course enrollments have more often remained level or, in some cases, fallen. Beyond the considerations of addressing a crisis in education caused by a severe shortage of qualified teachers, university faculty should not ignore a substantial source of interested students who are motivated to pursue study in our disciplines far beyond the elementary level.

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