Integrating Content, Pedagogy, and Reflective Practice: Innovative New Distance Learning Courses and Programs for Mathematics Teachers

Jeffrey Hovermill  
Northern Arizona University  
Jeff.Hovermill@nau.edu

Terry Crites  
Northern Arizona University  
Terry.Crites@nau.edu

Abstract

This article details the development of new courses and programs offered through a university distance learning initiative. These innovative courses build on national research and policy recommendations regarding the mathematical education of teachers. Course material, course evaluation, and student interview data are presented to shed light on two important themes: (a) How teacher content and pedagogical knowledge can be developed within courses and across a degree program and (b) how these teacher education goals can be met via distance learning. Students (classroom teachers) reported that the integration of content and pedagogy was a valuable feature of the program. Overall, students thought the program helped them be more effective teachers and would recommend the program to others. They especially appreciated the flexibility and convenience the distance programs provide.

Background and Significance

The No Child Left Behind Act (2001) requires each state to put a highly qualified mathematics teacher in every public school classroom. Arizona, like many other states, is struggling to meet the demands of the high number of mathematics teachers who are seeking ways to meet the “highly qualified” requirement. Surprisingly, this demand did not translate into a greater enrollment of teachers in post-undergraduate mathematics and mathematics education courses at our university. Two years ago, we found ourselves trying to understand why, in this time of emphasis on ensuring highly qualified mathematics teachers, fewer teachers were enrolling in our university post-undergraduate mathematics teacher education degree programs, and we sought to examine and address this paradox.

Distance learning administrators initiated focused conversations with school district personnel across the state and found out that many of the teachers who were seeking certification or advanced training were place-bound and simply unable to travel to the university to take courses. When queried about whether they would be interested in participating in high-level, relevant coursework via distance learning, the answer was unequivocally yes. With this information in hand, university distance learning administrators saw an opportunity to increase university enrollment and provide service courses to the high need area of mathematics education across the state. They, therefore, offered monetary and technical support for mathematics department faculty to develop mathematics education courses via distance delivery methods.

These distance learning office findings and support provided impetus for the mathematics department to pay extra heed to the recommendations made by mathematicians and mathematics educators on the Conference Board of Mathematical Sciences (CBMS) in The Mathematical
Education of Teachers (2001). In this book, the CBMS recommends that middle school and high school mathematics teachers are able to take extensive coursework that emphasizes “studying subject matter in relation to subject matter pedagogy (p. 2).” Hitherto the focus on these recommendations, most post-undergraduate level mathematics teacher education courses focused primarily on mathematics content, offered face-to-face, or on general pedagogy, offered on-campus or via distance learning.

This paper documents the journey we took to reshape the content and delivery of our post-undergraduate mathematics education courses and programs. We describe the genesis and development of the distance learning components of new Post-degree Certification (Post-Cert), Masters of Education with certification (M.Ed. w/ Cert.), and Masters of Arts of Teaching Mathematics (M.A.T.) programs and explore three themes: a) how we strive to successfully intertwine opportunities for teachers to develop content and pedagogical knowledge within courses and across our degree programs, b) how this has been done within a distance-learning environment, and c) the response of students (teachers) to this new program. In the following sections, we will first describe our degree programs and then summarize quantitative and qualitative data analysis of course evaluations and student interviews in order to share the accomplishments, challenges, and future directions of our innovative programs.

Program Overviews

The editors of the National Research Council (NRC) book Adding It Up: Helping Children Learn Mathematics, proclaim that to improve mathematics teacher performance and student learning “teacher’s need coursework that reflect a serious examination of the nature of mathematics that teachers use in the practice of teaching” (Kilpatrick, Swafford, & Findell, 2001, p. 375). Responding to national research and policy recommendations for mathematics teacher education, twelve new mathematics education (MAT) courses, which emphasize the connections between mathematics content, effective pedagogy, and reflective practice were developed. Two of these courses serve to replace normal undergraduate methods of teaching secondary mathematics courses for students who already have an undergraduate degree in a scientific field other than mathematics education and want to quickly pursue post-degree teacher certification. These initial methods courses also serve as prerequisite requirements for those who want to pursue the longer M.Ed. with Cert. degree program. The ten other new mathematics department courses can be used toward fulfilling requirements for the M.Ed. with Cert. and M.A.T. degree programs along with already existing College of Education distance learning courses. Both the M.Ed. with Cert. and the M.A.T. programs are 36 credit-hour programs. For the M.Ed. with Cert. program, prospective teachers must complete 12 credit hours from the mathematics department and 24 credit hours from the College of Education (COE). For the M.A.T. program, currently certified teachers must complete at least 27 credit hours from our newly developed MAT courses, and 9 credit hours of COE courses. Post-Cert, M.Ed. with Cert., and M.A.T. degree program requirements can be found at the following web sites, respectively,

http://www4.nau.edu/cstl/cstl/site/acad_prog/arul/index.html
http://coe.nau.edu/academics/inl/programs.php#seccert
http://www.econs.nau.edu/Academic/Math/degreePrograms/MATinMathematics.shtml

The multiple paths to teacher licensure and professional development that these programs offer, and the fact that newly developed courses can count towards different degree programs, has been a boon for recruitment and retention of students to the university and is a key recommendation for other university administrators. More information about these courses is described below.

Four of the ten new masters’ degree level courses focus more heavily on content than the other six courses. These four content courses follow CBMS’s call for classes “that connect the major mathematical strands in courses for mathematics majors with school mathematics” (2001, p. 24).
Therefore, these four content courses follow the development of the mathematical topic areas of algebra, geometry, probability and statistics, and calculus from the middle grades through graduate school. Within these “connections” courses, students study the links between, for example, how the concept of rate of change begins concretely in lower grades and becomes more formalized throughout algebra and calculus. This investigation of how concepts build across the grades should, ideally, deepen teachers’ own content understandings and aid their ability to develop important ideas for their students’ learning (Kilpatrick et al, 2001). University-level texts, grades 7-12 standards-based curricula, state and national standards, and research on teaching and learning are used in all courses to reach these goals. Brief descriptions of these content courses are below.

**MAT 504: Connections – Algebra and Number Theory**: This course addresses the teaching and learning of the following content areas: rings, fields and groups, arithmetic and congruence within the integers, and isomorphisms.

**MAT 505: Connections – Calculus**: This course addresses the teaching and learning of the following content areas: functions, sequences and series, limits, continuity, derivatives, integrals, introductory differential equations, and introductory analysis in the real number system.

**MAT 506: Connections – Geometry**: This course addresses the teaching and learning of the following content areas: axiomatic foundation of Euclidean and non-Euclidean geometry, transformations, geometric applications of trigonometry, visualization, geometric modeling, and graphs.

**MAT 507: Connections – Probability and Statistics**: This course addresses the teaching and learning of the following content areas: data collection, descriptive statistics, counting techniques, probability, simulation, random variables, probability distributions, correlation, and inferential statistics.

All four of these courses aim to support teachers to (1) become more familiar with mathematics content and (2) reflect on how this content knowledge, as well as the pedagogical knowledge gained through readings, discussions, and activities may help them become better mathematics teachers. This goal is actualized via a cohesive focus on the integration of content, pedagogy, and reflective practice. Also, noteworthy, is the fact that these courses were co-developed and are co-taught by mathematics and mathematics education faculty.

Course participants come to better understand the nuances of what national and state mathematics standards expect students to learn and strategies to help their students to be successful. Throughout these courses, students read, reflect on, and participate in on-line discussions about research-based and practitioner-oriented journal articles addressing issues related to the teaching and learning of mathematics (e.g., various models of mathematics learning trajectories; research on common student misconceptions, and multiple examples of curriculum, instruction, and assessing strategies). Instructional technology is embedded throughout the courses to support teacher content learning and to provide them with resources and practice regarding the effective use of educational technology in their own classrooms. Finally, students are encouraged to try out and discuss course tasks with their own students so there are direct connections between course material and their own instructional practices.

The other six MAT courses focus even more heavily on pedagogy and reflective practice than the previously described four courses. CBMS states “teachers need knowledge of the historical, cultural, and scientific roots of mathematical ideas and techniques” (2001, p. 2). Therefore, these courses involve teachers in praxis regarding how to best help their students learn. Most of these courses involve an action project where students are expected to more formally apply and study course material within their own instructional contexts. Brief descriptions of these pedagogy courses are below.
MAT 500: Reflections On/In Mathematics Education: This course facilitates reflection regarding effective mathematics education and involves teachers in collaboratively researching and revitalizing their own mathematics teaching.

MAT 501: History and Philosophy of Mathematics Education: This course focuses on the historical underpinnings of the field of mathematics education by identifying issues and forces that influence curricular and philosophical change in mathematics education.

MAT 502: Problem Solving Theory and Practice: This course focuses on theoretical pedagogical aspects of problem solving and the examination of curricular materials, teaching strategies, and evaluation techniques.

MAT 508: Technology in Mathematics Education: This course focuses on an examination of research and practice regarding the effective use of technology within school mathematics.

MAT 601: Seminar in Mathematics Education: This course investigates special topics in mathematical education. (May be repeated for credit.) The last topics class was Equity Education for Mathematics Teachers and the next one will be on the topic of assessment.

MAT 602: Research Methods in Mathematics Education: This course focuses on research within the field of mathematics education, including a study of research methodologies and their contributions and limitations and an examination of relationships between research and classroom practice.

MAT 500 is the only hybrid course in the program. The instructor of this course, and first author on this paper, has extensive experience supporting teachers in collaborative reflective practice (Hovermill et al., 2003; Hovermill Shamatha, 2007) and distance learning supports his travel to visit teams of course students as they enact their projects. This travel allows for the growth of a sense of community and, due to a shared purpose of improving teaching and learning, provides a valuable face-to-face component to an otherwise completely distance program (other than on-campus final comprehensive exams for the M.A.T. program). Prior research (Paloff & Pratt, 1999) and findings from this initiative suggest that administrators are recommended to also consider ways to provide personal and community oriented feature to their distance programs.

The above described courses are offered on a two year rotation, one content and one pedagogy course each semester. After one initial rotation of these courses, we stepped back to aggregate and analyze data on how the program was being received by participating students. The next sections of this paper describe our data collection methods and findings.

**Methodology**

To formatively evaluate the effectiveness of the program and guide subsequent development and revision of the MAT courses, we endeavored to collect and analyze quantitative and qualitative data through course enrollment, course evaluation, and student interview data. Numeric course enrollment and course evaluation data were organized and are summarized in the results sections below. Furthermore, the first cohort of M.A.T. degree students were invited to participate in a short, open-ended, anonymous interview, administered through the university distance-learning office, and was offered a $20 gift certificate to the university bookstore as compensation for their time. Respondents’ comments were aggregated by theme (Spradley, 1980) to search for patterns in responses. The results of this qualitative data analysis in regards to the two primary M.A.T. program goals of (1) providing teachers opportunity to enhance their content and pedagogical knowledge and (2) providing a meaningful distance learning environment are shared below.
Results

Since the new MAT courses have been offered, the number of enrolled and graduating students has greatly increased (see Table 1 below). In fact, more mathematics teachers are currently certified and advanced through our university programs than through all the other university programs across the state combined. Course evaluation ratings have also shown a high level of satisfaction (see Table 1 below).

Table 1

Comparisons of Selected Features of Old Vs. New MAT Courses

<table>
<thead>
<tr>
<th>Source of Data</th>
<th>Old MAT courses</th>
<th>New MAT courses</th>
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<tbody>
<tr>
<td>Number of courses offered per academic year</td>
<td>2 (both over the summer)</td>
<td>10 (4 Spring, 4 Fall, 2 Summer)</td>
</tr>
<tr>
<td>Total number of students enrolled per year in MAT courses</td>
<td>About 50 students enrolled per year, most of which were M.Ed. majors</td>
<td>About 150 students enrolled per year, mostly M.A.T, with many M.Ed., and Post-Cert. majors</td>
</tr>
<tr>
<td>Ratings to Course Evaluation Question “My general estimate of this course”</td>
<td>Most courses were offered over the summer without formal course evaluation.</td>
<td>Average 4.2 on 5 point scale.</td>
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Drop, fail, withdraw (DFW) rates for these new courses remain low (< 10% overall) due to clear communication about content and requirements for the courses and consistent enforcement of prerequisite criteria (satisfactory completion of initial mathematics teacher education coursework for master’s degree courses and satisfactory completion of prerequisite mathematics coursework for mathematics heavy courses).

When asked, “What originally attracted you to this M.A.T. program?”, almost every teacher commented that they thought the education they received through the program would help them be a more effective teacher. Most also cited how they really valued the flexibility the distance-learning program allows, while several also responded that their new degree would increase their salary and/or career options. Our two main program themes, the effort to integrate content, pedagogy, and reflective practice within and across courses, and the affordances and constraints of distance learning coursework, are discussed below.

When prompted, all interviewees agreed that they would recommend this program to other teachers as summarized by the following response, “Regardless of if it were online or in person, I would recommend this program for a teacher wanting to grow better in their knowledge of math and how to teach it.”

**Program Goal: Integrating Content, Pedagogy, and Reflective Practice**

Most teachers felt that the M.A.T. goal of integrating content and pedagogy was being achieved, as summarized by the comment,

> I think they have done an excellent job of integrating both of those aspects. While I was learning the content, I was also learning some interesting pedagogical things that I could immediately put into practice. Every single course made me reflect pretty deeply on my own practices.
Several teachers shared more specific feedback about the valuable ways that mathematics content was treated in the MAT courses. Their comments included, for example, “It gives me a deeper understanding of the math that I'm teaching, what it's leading towards.” Another comment, which highlights why it is important for teachers develop deeper content understandings, read,

> I would definitely agree my background knowledge has increased tremendously. I can see why we teach certain things better and how to prepare [students] for things. It also gives me more of a background so I can solve some of the problems I already knew how to do in more ways so that as kids can do them in their own different ways and I can see fallacies in their work or I can see how it's going to work.

Almost every respondent valued the pedagogical and reflective practice components of the program, as represented by the comment, “The things that I learned online I was able to apply in my classroom. I had to do different projects and it was neat because I could experiment with my students the things that I was learning in class, which was really helpful.” This idea of putting ideas into practice was also captured by the following response,

> We did case studies where we went and did hands-on type action projects. We took our pedagogy into practice with an action project. That got you right into the content in that regard. That was, to me, the number one thing. I would venture to say that's the most rewarding thing that I got from the classes.

**Program Goal: Distance Learning vs. Face-to-Face Courses**

Participants responded overwhelmingly that they would recommend this program to other teachers. One respondent summarized “The content of the courses is just as good, if not better, than any face-to-face courses I've had.”

Students particularly valued the freedom the online courses provided to plan when during the week they wanted to complete course tasks. One teacher explained, “I like that I don't have to drive [to the university] for every class. I can log on whenever I need to. That's my favorite part.” Another student shared, “The main draw for me was the flexibility they provide so that I was able to keep the life that I have with teaching full-time and the other responsibilities that I have.”

The most difficult courses for student to complete at a distance were the more content-focused courses. One student explained,

> It was harder than a regular in-person math class because in math class you can ask the teacher questions right away. Online, the professor was always available to answer questions if you had them to ask, but it seemed like I had to do a lot more on-my-own learning than I would have if I was in a class where we would have lectures, where there would be more explanation and stuff like that. Learning the math online has been difficult.

Course evaluation feedback demonstrated that even though teachers found these content courses challenging, they really valued the opportunity to be exposed to more content and teaching and learning preparation.

> I was not only able to review the fundamental concepts, I was also able to look at the way students learn these ideas. I was learning material that I could use right away in the real world. This also really helped me to keep everything in perspective and keep
my focus. As I went through the content, I not only learned the material deeper I also learned how my students would look at the material and their biggest challenges.

**Discussion**

CBMS states that high school mathematics teachers should develop:

- Deep understanding of the fundamental mathematical ideas in grades 7-12 curricula and strong technical skills for application of those ideas.
- Knowledge of the mathematical understandings and skills that students acquire in their elementary and middle school experiences, and how they affect learning in high school.
- Knowledge of the mathematics that students are likely to encounter when they leave high school for collegiate study, vocational training, or employment.
- Mathematical maturity and attitudes that will enable and encourage continued growth of knowledge in the subject and its teaching.

We feel, as supported by participants’ evaluations, that the new online MAT courses and programs at our university are meeting the CBMS’s rich goals for mathematics teacher education.

While we are pleased with the initial successes we have achieved with our MAT courses, as attested by some comments above, we are still striving to continually improve the balance between content and pedagogy. The biggest challenge for us has been learning how to explain and manage the more content oriented connections courses. By examining course and program data, we feel we can improve the ways we describe our course goals and the need for teachers to know more content than only what they teach to their students. We are doing this by including more CBMS (2001) background information in our program and course descriptions. We are also working to provide more support to students as learners by more efficiently collecting and returning homework electronically, holding virtual office hours using the live multimedia web-conferencing program *Elluminate* (2006) and organizing examination proctors in rural areas. In our opinion, *WebCT Vista*, the online learning environment these courses are facilitated within, actually requires a higher level of involvement from most students than does a traditional course, since it is not an option to remain uninvolved in class discussion. All students must think about and post answers to assignments in the online courses, where in face-to-face classes some students may choose not to volunteer.

It is rewarding for us to hear comments from students such as “It has been really helpful to take these classes while I'm a full time teacher because every single day I'm practicing for real in my classroom,” and

The classes have made me really think about how I was teaching, how I can make a difference in everybody's lives. I think the whole point of being a better teacher is making sure you can reach everyone and make sure everyone understands the math, not just the ones that always get it. I think all of my classes helped me think about how I could better teach my students.

By studying our successes and challenges, we have gained valuable information about what is working well and what can still be improved. In particular, we still hope to improve the content and delivery of our mathematically focused courses. As we continue to address this issue, we will continue to share our results. We hope that by sharing details and results of our courses and programs more universities will be able to think about how to provide robust opportunities to develop and improve mathematics teacher education. As they do so, we recommend that they keep in mind the importance of allowing multiple entry points for those at various stages of their careers and that they heed the recommendations for the integration of pedagogy and content in theory and
practice.

References


