NORTH CAROLINA NAEP: APPLYING THE NATIONAL ASSESSMENT OF EDUCATIONAL PROGRESS WITHIN PRESERVICE TEACHER EDUCATION

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This study developed twelve instructional modules based on the National Assessment of Educational Progress for mathematics content and methods courses for preservice elementary and middle school teachers and examined their impact on PSTs' mathematical content knowledge and self-efficacy beliefs about teaching mathematics. The modules help preservice teachers: (1) improve their mathematical content knowledge, (2) learn how to use effective methods to teach mathematics; and (3) become aware of uses of NAEP. Mathematical content knowledge was measured by instruments from the Learning Mathematics for Teaching project and mathematics teaching efficacy beliefs were measured by the Mathematics Teaching Efficacy Beliefs Instrument or the Yackel Beliefs Survey. Modules were found to increase PSTs' mathematical content knowledge for teaching and improve their teaching efficacy beliefs.

Keywords: Teacher Education–Preservice; Teacher Knowledge; Teacher Beliefs

National reports (Project Kaleidoscope, 2006; National Academies, 2003, 2008; Ball, Ferrini-Mundy, Kilpatrick, Milgram, Schmid, & Schaar, 2005) pointed out the urgent need to improve the quality of science, technology, engineering, and mathematics (STEM) education programs. The National Academies (2006, cited in PKAL, 2006) advised increasing "America's talent pool by vastly improving K–12 science and mathematics education" (p. 4-2). Such progress rests on improved mathematical education of teachers. Morris (2006) stated, "Preservice teachers rarely exit their mathematics teacher education program as experts" (p. 471). The question therefore becomes, how do mathematics teacher educators help PSTs better develop their expertise, especially during their early careers? It is difficult to address the learning needs of preservice teachers (PSTs) due to the large number of concepts, skills, and strategies that must be acquired at a high level of competence to teach successfully. This fact must be kept closely in view by faculty of mathematics content and methods (MC&M) courses for teachers. We must carefully examine the goals of these courses and ask: (1) *Are we giving students enough experiences in the areas we expect them to master?* (2) *Do they have sufficient opportunities to consider problems from both students' and teachers' viewpoints?* and (3) *Do they have sufficient opportunities to examine both student work and student achievement data?*

It is insufficient to discuss problem solving, development of student conceptions, and assessment of mathematical learning, in abstraction. Preservice teacher education must have a strong student focus and be rooted in authentic classroom data. Novices need specific experiences in how to analyze student work, assess student understanding, and in scoring student work with various rubrics. Previous researchers (Morris, 2006; Osana, Lacroix, Tucker, & Desrosiers, 2006) reported the benefits of asking PSTs to analyze mathematics teaching episodes from real practice. Morris (2006) described a study where PSTs' abilities to analyze videotaped teaching episodes differed markedly on the basis of whether they were told

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beforehand that a lesson was unsuccessful or whether they had to make this determination independently. Morris's study suggests that what PSTs *focus on and attend to*, in analyzing teaching and student performance, is linked to what experiences and guidance they receive from teacher educators.

Current efforts to improve mathematics teaching recognize the importance of helping teachers (a) gain depth in their mathematical content knowledge, (b) master specialized content-related strategies needed to help children learn mathematics, and (c) learn pedagogical and assessment practices to improve the quality of teaching and student learning (Hill, Rowan, & Ball, 2005; Ball & Hill, 2004; Ball & Bass, 2000). We believe that the analysis of sound mathematical tasks, discussion of explanations for mathematics procedures and concepts, careful analysis of student work, and discussion of assessment practices should be a focus of preservice mathematics content and methods courses and that these experiences should occur across the teacher education program. The North Carolina NAEP project found preservice teachers to be especially receptive to NAEP-related instruction that was clearly linked to examples of student work, analysis of that work, and examination of student performance data.

Purpose

The goal of the *North Carolina NAEP: Improving Mathematics Content and Methods Courses* project was to modify materials from *Learning from NAEP: Professional Development for Teachers* (Brown & Clark, 2006) for use in preservice mathematics content and methods courses, to expand the materials to include more recent NAEP assessment results, and to include, and focus on, more mathematics content. While NAEP produces a vast amount of data concerning students' learning and achievement, this wealth of data is not always used effectively within preservice teacher education courses to help PSTs become aware of what these data show. The project addressed three research questions, two of which are addressed in this paper:

1. How can mathematics content and methods (MC&M) courses for preservice undergraduates and graduate students be improved through the integration of NAEP?
2. How can NAEP-related materials be used in MC&M courses to help beginning teachers see the connections among the following areas: (a) teachers' content knowledge, (b) student understanding, (c) classroom assessment practices, (d) analysis of student performance data, and (e) use of NAEP data to address issues of equity?

The results described here explain the ways in which the modules appeared to influence preservice teachers' mathematical content knowledge and how they seemed to influence their mathematics teaching efficacy beliefs. Goals and outcomes of the project include:

1. The improvement of MC&M courses for elementary and middle school PSTs to produce teachers knowledgeable about mathematics content and pedagogy and knowledgeable about difficulties students have in learning mathematics topics.
2. The improvement of MC&M courses to produce teachers able to use NAEP and other assessment data to consider issues of equity and to modify teaching to address them.
3. Improving teachers' knowledge of various assessment strategies including designing and using problem solving rubrics.
4. The development of (a) multimedia materials that illustrate critical mathematics concepts, NAEP-related problems, examples of student errors, statistics concerning student achievement on NAEP problems, and activity sheets providing guidance for group analysis of this information within MC&M courses; and (b) a project website.
5. Enhancing instruction and communication between institutions within the North Carolina Community College system and the University of North Carolina system.

The project team involved mathematicians and mathematics educators from the following universities and community colleges: Appalachian State University, the University of North Carolina Charlotte, the University of North Carolina Wilmington, Forsyth Technical Community College, Mayland Community College, and Wilkes Community College. *The UNC Teacher Preparation Program Effectiveness Report*

(Henry, Thompson, Bastian, Fortner, Kershaw, Marcus, & Zulli, 2011) concluded that the following programs were outperforming their reference group comparisons in these areas:

> Appalachian State University – Elementary Program: *elementary mathematics*
> University of North Carolina Wilmington – Middle School and Secondary Mathematics Programs: *middle school and secondary mathematics*
> University of North Carolina Charlotte– Middle School Programs: *middle school mathematics* (Henry et al., 2011, p. 11)

Thus, we were able to integrate, within the project modules, instructional practices that have been deemed effective in improving teacher preparation at the participating institutions.

The project team included two practicing teachers, one from the elementary level (Ms. Anderson) and one from middle school (Mr. Schmal). These teachers helped the team link the NAEP assessment results to the realities of daily classroom practice through their contributions to the writing teams and through their commentaries concerning how NAEP data mirror the types of student work and difficulties that they observe in their classrooms. Twelve modules were produced, four for each of these levels: elementary, middle school, and community college. The community college modules are directed at undergraduate mathematics courses frequented by preservice teachers. The modules employ a variety of instructional approaches including: using active learning strategies; conducting analyses of NAEP results; conducting analyses of student work; developing understanding of the mathematics contained in NAEP problems; and developing awareness of NAEP rubrics and procedures for assessing student work. The elementary modules address the areas of: *fraction number sense*, *addition and subtraction*, *early algebra*, and *geometry*. The middle school modules include the topics: *proportional reasoning*, *geometric and spatial reasoning*, *linear growth and rates of change*, and *data analysis*. The community college modules cover the topics of*: algebra*, *probability*, *proportional reasoning*, and *spatial reasoning*. The study results suggest that seeing their college mathematics and mathematics education instructors model more inquiry-based pedagogical strategies positively influences and broadens PSTs' vision of effective mathematics instruction.

The modules are flexible allowing for inclusion within different course structures and time allotments. Each module contains:

1. Purpose
   a. Specification of the mathematical concept(s) addressed
   b. Specification of pedagogical approaches
2. Overview
   a. Module goals
   b. Module activities
3. Background and context notes
   a. Includes research brief concerning math concept and relevant pedagogical issues
   b. Includes discussion of common student errors based on research
   c. Examines NAEP student performance data in context of relevant research
4. Preparing to teach the module (Instructor notes not covered elsewhere)
5. Introductory PowerPoint presentation for the module (to be presented to PSTs)
   a. Specification of the mathematical concept(s) being addressed
   b. Specification of pedagogical issues addressed
6. *Teaching the Module* plan for the university/college instructor that provides:
   a. Goals and objectives of the module
   b. Time required for module
   c. What mathematics is addressed and grade band(s)
   d. How NAEP resources will be used
   e. Materials required
   f. NCTM Principles or Process Standards addressed
   g. NAEP Content Strand Emphasized

h. Description of class activities (Activities should include samples NAEP problems, student work, and performance data)
i. Directions for conducting class activities
j. Student activity sheets
k. Discussion guide

7. References

Each module includes recommended readings and Teaching Notes to help instructors implement the activities. The instructor can access PowerPoint presentations as well as a Moodle-based course shell that includes the instructional materials. Example modules are available on the project website http://ncnaep.rcoe.appstate.edu/. Online and face-to-face professional development opportunities are planned for 2013–15.

Method

Instructional modules based on NAEP data were developed and implemented in mathematics content and methods courses aimed at preservice elementary and middle school teachers who were enrolled at three universities and two community colleges from fall 2008 to spring 2010. Thus far, roughly 750 PSTs have been impacted by the project. External evaluators analyzed three data sources: (1) PSTs' performance on a mathematics knowledge assessment (LMT); (2) PSTs' responses to mathematics teaching beliefs questionnaires, the *Mathematics Teaching Efficacy Beliefs Instrument* (MTEBI) (Enochs, Smith, & Huinker, 2000) or the *Yackel Belief Survey* (Quillen, 2004); and (3) faculty responses to the *NC NAEP* workshop surveys and their reported use of *NC NAEP* modules. The sample included PSTs who were given a mathematics content knowledge test and a teaching self-efficacy questionnaire at the beginning and end of the semester. The project included sections of experimental courses at each university as well as control sections that did not use the project modules. The elementary preservice teachers were given the *LMT: Grades 4–8 Geometry* test or the *LMT: Elementary School Number Concepts and Operations–2004* test, dependent upon their specific course enrollment. The middle school preservice teachers were administered the *LMT: Middle School Number Concepts and Operations* test, as were the community college students. It is significant to note that the LMT tests do not just measure mathematics content knowledge; they measure a teacher's knowledge of mathematics for teaching. Thus, this data helps us learn not only how the PSTs think about mathematics concepts but it also helps us to form a picture of how they interpret possible student responses to certain mathematical scenarios. To ensure comparability across all data collected, the analysis included only students in each group, (e.g., course specific, higher education setting, and grade-level focus) for which evaluators were able to match both the pre-post scores on each instrument. After linking students with their pre and post scores, the evaluators conducted a range of statistical tests including significance and regular multiple regression tests, as well as item response analyses.

Key Findings

The results from the *NC NAEP Project* suggest that the National Assessment of Education Progress can inform instructional practice. This report shares findings based on the evaluators' analysis—using a mix of data from several instruments (i.e., *Mathematics Teaching Efficacy Beliefs Instrument* (MTEBI), the *Yackel Belief Survey* (YBS), and the *Learning Mathematics for Teaching instrument* (LMT)) used at different stages of the project, and with populations of students from 2 to 4-year undergraduates. Three main project components evaluated are discussed below: (1) PSTs' learning in terms of content knowledge and mathematics teaching efficacy beliefs; (2) learning by the college /university faculty impacted by the project; and (3) the quality of the modules and accompanying materials.

Impact on Pre-Service Teachers' Content Knowledge

Finding #1. Project faculty were differentially effective in increasing PSTs' mathematics content knowledge for teaching as measured with an LMT test. Because positive growth varied strongly across

students linked to different project faculty, the results suggest overall positive effects. The difference in faculty effectiveness is significant at $p \leq 0.01$. Over half of the project faculty had students who gained, on average, a standard deviation or more in post-test scores.

Finding #2. All PSTs showed improvement in their knowledge of mathematics, with elementary PSTs making the largest gains. Treatment elementary PSTs showed statistically higher gains in their pre-post knowledge of mathematics for teaching as compared to a control.

Elementary Pre-Service Teachers

The average number of correct items on the baseline LMT test for all pre-service elementary teachers was 10, while the average number correct on the post-test was 12.4. There was little variation in the test scores between students in the control and treatment groups—the average pre-test score was 10 for both groups, and the average post-test scores were 12 and 12.50 respectively.

The post-LMT test gain for elementary pre-service teachers corresponds roughly to a 2 to 3-item increase, per student, in the raw number of correct items. Considering that the assessment was not designed exclusively to match the curriculum of all or any particular course, this gain is a promising finding. The standard deviation of the pre and post-test scores for students in the treatment group were .892 and .626, respectively, making this gain a third standard deviation in size, and statistically significant at $p < .001$.

Pre-service teachers pre and post-LMT scores in spring 2010 were higher in the number of overall correct items by 2 than compared to teacher's pre-post scores in fall 2009. An analysis of matched items from the pre-post LMT showed that spring 2010 students performed significantly better on items designed to measure operations content knowledge than other students. Correct responses to items 5 and 8 were positively and strongly predictive of teachers' knowledge of mathematics, and higher raw scores than other matched items. These results suggest that as the project proceeded and the project modules were more effectively integrated within the courses, the benefits became more pronounced.

Middle School Pre-Service Teachers

The number of middle schools pre-service teachers for which there were matched pre-post test scores for was considerably smaller than the sets for the community college and elementary pre-service teachers. This data is reported for comparison purposes, but we suggest the results be viewed with caution because of the relatively high standard error compared to other sub groups. Analysis of the pre-post LMT scores for pre-service middle school teachers revealed a statistically significant increase in post-test scores at the 5 percent level overall, and in both fall 2009 and spring 2010.

Finding #3. Preliminary results indicate a high degree of correlation $r = 0.78$ between PSTs' personal beliefs of math and math instruction and their performance on the LMT. The relationship between knowledge of mathematics teaching was strongest with the personal efficacy sub-scale.

Impact on Pre-Service Teachers' Self-Efficacy

Finding #4. Evidence suggests that the *NC NAEP* modules used in different contexts influence PSTs self-awareness and confidence in their personal efficacy for mathematics and mathematics instruction. We examined the relative effects of instructional environment (2 or 4-year university/college) and instructor with different characteristics on PST outcomes. Four unique pair-wise comparisons of PST beliefs were conducted: (a) 4-year university PSTs relative to community college PSTs, (b) elementary school PSTs relative to middle school PSTs; (c) elementary pre-service treatment teachers relative to elementary pre-service control teachers; and (d) fall 2009 PSTs relative to spring 2010 PSTs.

Among the aggregate results on the MTEBI, PSTs responses indicate changes in nearly every personal efficacy item, with significantly positive changes ($p \leq 0.001$) on three items: (e.g., "I know how to teach mathematics concepts effectively"). In nearly every dimension (e.g., subject matter-knowledge, pedagogy and subject-specific pedagogy), PSTs from spring 2010 had markedly higher self-efficacy beliefs toward mathematics, with elementary PSTs showing dramatic shifts—both experimental and control. Both elementary pre-service and middle school PSTs from 4-year universities, showed a statistically significant

differential ($p \leq 0.001$ and $p \leq 0.05$, respectively) intra-group in their post-mathematics efficacy scores—indicating changes in their mathematics content and PCK.

Finding #5. At the end of the semester, PSTs, in general, noted changes in their attitudes that they can positively influence student learning—their belief in outcomes expectancy. Elementary and middle school PSTs from spring 2010 showed significant changes ($p \leq 0.05$) in their outcomes expectancy beliefs when compared to candidates from Fall 2009—both experimental and control.

Impacts on Faculty Instructional Practice

Finding #6. Project faculty found value in using project resources to improve their own instructional effectiveness. *NC NAEP* modules forged connections between mathematics content, instructional practice and assessment, to help faculty better prepare PSTs.

Finding #7. Non-project faculty found the *NC NAEP* materials very useful. They reported that the training and materials helped them form a personal action plan for using *NC NAEP* resources and illustrate concrete resources and strategies for improving students' preparedness.

Finding #8. *NC NAEP* resources helped to challenge participating faculty's preconceptions concerning their teaching of mathematics content and methods. Participating faculty recognized the importance of changing their practice to evaluate their students' preparedness and to emulate authentic classroom activities.

Conclusions

The *NC NAEP* modules had important effects on the development of PSTs' mathematical content knowledge, and improved their personal efficacy, outcomes expectancy, and attitudes toward mathematics. The modules provided a meaningful format from which to draw situated, authentic resources to support critical thinking and reflection about mathematics instruction. These modules have the potential to play a critical role in the preparation of high-quality, well-prepared teachers of mathematics. However, some limitations of the evaluation should be mentioned. While the LMT is a reliable measure of mathematical content knowledge for in-service teachers, its use with PSTs is preliminary (Gleason, 2010). To address this concern, we plan for future evaluations of the modules to validate individual LMT results using either an assessment of PSTs use of mathematics content during situated classroom teaching or using interviews where students explain their thinking and solution process to the test items. Gleason also suggests that the reliability of the LMT with preservice teachers is strengthened through the use of multiple instruments.

In addition to the findings discussed above, the project team submitted the modules to an external mathematics educator from the Pennsylvania State University for evaluation. The evaluator provided detailed feedback concerning the quality and utility of the modules, noting:

> Overall, I can see that the project has worked hard to integrate NAEP items, results, and student work into modules that are intended to be disseminated for use in PST education. Developing meaningful activities for PSTs is challenging; developing accompanying facilitator notes adds levels of difficulty to the task. The developers of the materials are to be commended for their work thus far, particularly in the area of integrating NAEP into your materials.

Some of the evaluator's suggested revisions include: (a) limiting the scope of some of the modules, particularly the community college materials, to make them easier for instructors to implement; (b) addressing the issues associated with making referenced video clips more accessible; and (c) changing some of the facilitator notes to provide more guidance to instructors concerning how to best implement the modules. We are making revisions to the modules based on this helpful feedback.

Another indicator of the quality of the project modules is their adoption for use in selected courses within a new multi-university program in North Carolina for an *Add-on Certificate in Elementary Mathematics* (which is similar to a K–5 mathematics specialist). Evaluation of the pilot add-on certificate

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program showed improvements in mathematics content knowledge of the teachers enrolled as compared to a control group.

This project provides an example of how different communities of professionals can contribute to the effectiveness of mathematics teacher preparation programs. Mathematicians and mathematics educators, including instructors from various levels of higher education (doctoral institutions, 4-year institutions, and community colleges), and classroom teachers all have a crucial role to play in the development and implementation of authentic instructional resources in mathematics teacher education. Such cooperation among professionals and institutions facilitates transitions across the continuum, including the transition that students make as they progress through a teacher education program and emerge as an effective beginning mathematics teacher.

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