REFORM TEACHING IN MATHEMATICS AND SCIENCE COURSES—A FOLLOW-UP EVALUATION

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Introduction

The history of educational reform at all levels surely shows that significant and long-lasting change is not easy. Influencing change in college courses can be especially difficult because of the independent nature and disciplinary expertise of the professors who teach those courses. While external grants from prestigious foundations can certainly help convince college professors to modify their courses, a continuing question is whether those changes continue after that external funding and support disappear. What characteristics of those redesigned courses will continue after the initial reform effort ends?

The purpose of this article is to present the results of a follow-up evaluation on a six-year project to develop more effective introductory college mathematics and science courses, especially for those students planning to become elementary and middle school teachers. Faculty at seven Virginia higher education institutions collaborated to develop introductory mathematics, science, and education courses that offered a broad-based core of knowledge taught through "best teaching practices" to enhance student learning. The mathematics and science faculty were also asked to focus especially on the most important disciplinary knowledge for those students who planned to become K-8 teachers.

From 1993 to 2000, the National Science Foundation funded the Collaboratives for Excellence in Teacher Preparation (CETP) program to encourage educational institutions to reform the initial training of K-12 teachers in order to produce future teachers well prepared in mathematics, science, and technology. One of the main CETP goals was to encourage arts and sciences college faculty to work with education faculty and local school teachers to develop mathematics and science instructional experiences that help students learn in-depth subject matter and essential teaching skills.

The theoretical framework for reform programs such as CETP can be clearly found in the mathematics and science standards-based reform efforts of the past ten years. Twelve years ago, the American Association for the Advancement of Science began Project 2061 with the explicit, long-term goal to reform K-12 education to produce science literate graduates. Their 1989 report, *Science for All Americans*, identified what all students should know and be able to do in mathematics, science, and technology after thirteen years of schooling [1]. In 1993, Project 2061 published *Benchmarks for Science Literacy* that translates the literacy goals of *Science for All Americans* into explicit learning objectives by the end of grades 2, 5, 8, and 12 [2]. The National Science Education Standards released in December 1995 provided a series of standards for the following: 1) science teaching; 2) professional development of teachers; 3) teachers' development of professional knowledge and skills; 4) science education assessment; 5) content standards organized by K-4, 5-8, and 9-12 grade levels; 6) school district science program standards; and, 7) the science education system beyond the school [3]. Among the six science teaching standards presented in that report, three—the calls for inquiry-based science programs, for the teacher to become a facilitator of student learning, and for the ongoing assessment of teaching and student learning—are especially important to reforming college science courses.

Methods

The Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) was established in May 1996 and originally consisted of the following: 1) four-year institutions (Virginia Commonwealth University, Norfolk State University, Mary Washington College, and Longwood College—faculty from UVA and the College of William & Mary joined VCEPT in later years); 2) two-year institutions (J. Sargent Reynolds Community College, Tidewater Community College, and Germanna Community College); 3) community-based educational institutions (the Science Museum of Virginia and the Virginia Mathematics and Science Center); and, 4) local school systems. The Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) was engaged in formal project activities for six years until May 2002. As part of a more extensive CETP impact study, the National Science Foundation funded a three-year evaluation follow-up in 2002 on the effects of the VCEPT activities. This three-year follow-up study examined the impact of VCEPT (in terms of both influence and sustainability) on college professors, teacher graduates, professional teachers in the field, and the policies of the Virginia Department of Education. Only the impact on higher education faculty will be examined in this article.

One of the main VCEPT project goals was to facilitate a re-examination of introductory college mathematics, science, and education courses taken by students preparing to be K-8 teachers. Typically, these introductory courses were also used to satisfy the general education requirements of other students not planning to become teachers. While a few of these students would choose to major in mathematics and science, these were normally the final mathematics or science course for most students in these courses.

Teams of college and K-8 faculty worked on the redesign of specific courses at each of the VCEPT institutions. They were guided by course development principles which the entire VCEPT project working group had approved by consensus. The choice of specific courses' goals, activities, and assignments were to be guided by the following fifteen instructional characteristics:

1) active student learning
2) up-to-date teaching technologies
3) connections to other related disciplines
4) connections to the natural world
5) mixture of breadth and depth in coverage
6) interesting and intellectually involving concepts
7) critical thinking about current events
8) practical applications to students' own lives
9) effective interactions among students
10) opportunities to collect pertinent information
11) opportunities to organize information
12) opportunities to analyze information
13) opportunities to communicate conclusions and ideas
14) ethical and social implications in the world
15) different methods of assessing student performance

Fifty-eight VCEPT "reformed" courses were developed at five of the original VCEPT project institutions—Longwood University (LWU); Norfolk State University (NSU); University of Mary Washington (UMW); Virginia Commonwealth University (VCU); and J. Sargeant Reynolds Community College (JSRCC)—using these guiding principles. Throughout the original six-year VCEPT project, these courses were regularly evaluated through classroom visits by project evaluators, interviews with course instructors, and end-of-course evaluations by students. The results of these efforts were shared with course instructors through individual feedback reports. Combined course evaluations were also shared with VCEPT project members and the National Science Foundation through annual VCEPT reports.

For the follow-up evaluation, a sample of these courses was selected to investigate to what degree the courses still exhibited those principles after the original VCEPT project ended. In addition, the evaluation examined how well those reform course characteristics enhanced students' learning. During the fall and spring semesters of the 2003-2004 academic year, eighteen different courses (with 1-5 different sections of each course) were evaluated using an end-of-course student questionnaire (see Appendix A) that asked students to rate to what degree the course exhibited these fifteen VCEPT course development principles and the degree to which they contributed to their learning in the course.

The number of courses (and sections of the same course) at each institution was the following: one course (6 sections) at JSRCC; two courses at UMW (1 and 2 sections); two courses at VCU (1 and 4 sections); five courses at NSU; and, seven courses (1, 2, 3, 4, 4, 4 and 5 sections) at LWU. The number of students completing the follow-up VCEPT course evaluations was 112 at JSRCC, 73 at UMW, 237 at VCU, 129 at NSU, and 459 at LWU for a total of 1,010 students. The courses were chosen by institutional VCEPT coordinators to be representative of the "typical" VCEPT reform course. This purposeful sampling method would adequately represent the type of mathematics, science, and education VCEPT reform courses still being taught at each institution.

Results

The students taking the VCEPT reform courses at all five of the institutions provided remarkably consistent feedback about their course experiences. At all five VCEPT institutions, the students identified "active student learning" as the most frequently encountered characteristic of the fifteen identified VCEPT course characteristics and also the most valuable characteristic for their learning in the course. Typically, about 85% of the students indicated that "active student learning" occurred systematically or customarily in all of their classes. On a 5-point scale—where 1= Systematic use (100% of classes); 2= Customary use (75%-99% of classes); 3= Frequent use (50%-74% of classes); 4= Moderate use (25-49% of classes); and, 5= Occasional use (0-24% of classes)—"active student learning" averaged a 1.91 rating for the degree to which it occurred in their classes. While the use of a mean rating with these five ordinal categories can be misinterpreted, the mean rating is included here because it provides a helpful indication of the distribution of the students' responses among the choices.

Other most frequent VCEPT course characteristics that students reported being a part of their courses did vary somewhat among institutions, but there was still much consistency in the students' ratings. At Longwood University, the second through fifth most frequently noted course characteristics were "assessment of student performance in different ways," "connections to the natural world," "mixture of breadth and depth in coverage," and "opportunities to organize information." At Norfolk State University, the second through fifth most frequently noted course characteristics were "interesting and intellectually involving concepts," "opportunities to organize information," "up-to-date teaching technologies," and "opportunities to analyze information." At the University of Mary Washington, the second through fifth most frequently noted course characteristics were "effective interactions among students," "up-to-date teaching technologies," "practical applications to students' own lives," and "opportunities to communicate conclusions and ideas." At Virginia Commonwealth University, the second through fifth most frequently noted course characteristics were "effective interactions among students," "opportunities to analyze information," "connections to the natural world," and "opportunities to communicate conclusions and ideas." At J. Sargeant Reynolds Community College, the second through fifth most frequently noted course characteristics were "connections to the natural world," "interesting and intellectually involving concepts," "opportunities to analyze information," and "mixture of breadth and depth in coverage." While the students' reported use of these course characteristics did vary among the different types of mathematics, science, and education courses, students were quite consistent in reporting "customary use" (defined as occurring in 75% to 99% of their classes) for these top five characteristics.

These students were also asked to rate the importance of these fifteen VCEPT course characteristics in helping them to learn in their course. The number one rated characteristic by the students across all VCEPT institutions was "active student learning" with a mean rating for all forty-two VCEPT courses/sections sampled of 1.47 on a 5-point scale, where 1= Very Important, 2= Important, 3= Unimportant, 4= Detrimental to Your Learning, and 5= Not Applicable or No Opinion. Again, the mean rating is used for these five nominal categories to represent the overall ranking of the students for each characteristic.

"Interesting and intellectually involving concepts" was rated the second most valuable course characteristic for student learning at LWU, NSU, and JSRCC while being rated third most valuable at VCU and fifth most valuable at UMW. "Assessment of student performance in different ways" was rated second most valuable at VCU, third most valuable at LWU, fourth most valuable at UMW, and fifth most valuable at JSRCC. "Practical applications to students' own lives" was rated second most valuable at UMW and fourth most valuable at LWU. Two other course characteristics made the top five for their value to student learning in three different institutions: "effective interactions among students" and "up-to-date teaching technologies." "Opportunities to analyze information" and "opportunities to communicate conclusions and ideas" made the top five at two of the VCEPT institutions.

There was again much consistency among the students' ratings of the least frequently encountered course characteristics. These four course characteristics were always rated the least frequent components of the VCEPT courses, although the exact twelfth to fifteenth order did differ among the VCEPT institutions: "critical thinking about current events," "ethical and social implications in the world," "connections to other related disciplines," and "practical applications to students' own lives." The three lowest-rated course characteristics on value to students' learning were also the same among all the four-year VCEPT institutions with the exact order at the bottom again differing slightly: "ethical and social implications in the world," "critical thinking about current events," and "connections to other related disciplines."

Discussion and Conclusions

The VCEPT course evaluation follow-up data support the conclusion that project-initiated changes to mathematics, science, and education courses are still reflected in students' perceptions three to five years after the initial course modifications. These new students' end-of-course evaluations of their reform mathematics, science, and education college courses show that the class activities and assignments have continued to exhibit most of the VCEPT instructional characteristics that faculty put into their redesigned courses.

"Active student learning" has continued to be the most important course element for both instructors and students. While the exact nature of these activities differs among the courses, students do perceive an overall instructional commitment for student-centered learning rather than teacher-centered lecturing. While there was some variation among the rest of students' rankings at different institutions, the course characteristics of "opportunities to analyze information," "connections to the natural world," "interesting and intellectually involving concepts," "mixture of breadth and depth in coverage," "effective interactions among students," "up-to-date teaching technologies," and "opportunities to communicate conclusions and ideas" were typically seen as customarily used in the reform courses.

When students were asked to indicate which course characteristics contributed most to their learning, "active student learning" was the highest ranked instructional component. Since this was also the one course characteristic most frequently identified with the reform courses, this finding suggests that students' learning was indeed enhanced by the project-based course changes. "Interesting and intellectually involving concepts" and "assessment of student performance in different ways" were the next two highest-ranked contributions to students' learning. "Effective interactions among students," "up-to-date teaching technologies," "practical applications to students' own lives," "opportunities to analyze information," and "opportunities to communicate conclusions and ideas" were the other highest-ranked contributors to student learning. All of these except assessment were also perceived as frequently occurring in the reform courses.

Examining the least frequent and least valuable course characteristics students identified, at least two interpretations of these findings are possible—the less frequent use of these characteristics made them less valuable to the students or the students did not find inclusion of these issues helpful to learning the basic content of the courses. Interviews with faculty did reveal that instructors found including course material that provided "ethical and social implications in the world," "critical thinking about current events," and "connections to other related disciplines" the most challenging of the instructional characteristics to address.

While this follow-up evaluation provides positive evidence that the VCEPT reform courses have consistently retained the VCEPT course principles, additional kinds of evidence could have strengthened that conclusion. Most of the instructors who redesigned the courses are still the instructors-of-record. When new professors start teaching these courses, will they continue the same objectives, activities, and assignments? Whether the current professors mentor their colleagues and convince them of the value of these reform course characteristics remains an open question.

This follow-up evaluation used students' judgments because they were the target consumers for the course changes. However, the evaluation would have been stronger if an objective measure of student learning was available for students taking the VCEPT reform courses. While each instructor did formally assess and grade each student's learning, the changes in the courses made comparisons with earlier students in the pre-reform courses impossible. The use of any standardized assessment measure given as a pre-test and post-test was also not an evaluation strategy that the instructors embraced.

In conclusion, this follow-up evaluation has shown that college course development initiated by a formal NSF-funded project can be maintained after that funding ceases. Since the sustainability of project-initiated changes is an important goal of such foundation-funded projects, this evaluation should encourage future efforts to help mathematics, science, and education faculty reconsider the way they help undergraduate students learn the core concepts and principles that help them learn—and, in some cases, teach—those fundamental disciplinary ideas.

References

[1] *Science for All Americans*, American Association for the Advancement of Science, Washington, DC, 1989.

[2] *Benchmarks for Science Literacy*, American Association for the Advancement of Science: Project 2061, Oxford University Press, New York, 1993.

[3] *National Science Education Standards*, National Research Council, Washington, DC, 1996.

Appendix A

Virginia Collaborative for Excellence in the Preparation of Teachers

Fall 2003 Evaluation Questionnaire

Your instructors have been participating in a National Science Foundation project to identify and implement "best practices" for college mathematics and science instruction. Please complete the following questionnaire so that we can use your feedback in the future development of this course. Your anonymous opinions will be returned to the project evaluator who will summarize them for the instructors and the National Science Foundation. Since we will be summarizing your responses as group data, your individual opinions will remain confidential. However, we are asking for some biographical information to see how students' views are influenced by their year in school or career aspirations. Thank you in advance for taking the time to respond thoughtfully to these questions.

Please use a No. 2 pencil to fill in the appropriate circle on the General Purpose Answer Sheet to record your answers. In the Last Name space print the abbreviation for your course and section number, such as MATH 106-01, CMSC 128-03, or BIO 121-02, but you do NOT need to mark the circles under those letters and numbers.

<u>Feedback on Course</u>

Please use the 5-point rating scale on the right for items 1-15 as you describe the following characteristics of this course.

To what degree did classes in this course include

1. active student learning	A = Systematic use (100% of classes)
2. up-to-date teaching technologies	B = Customary use (75%-99% of classes)
3. connections to other related disciplines	C = Frequent use (50%-74% of classes)
4. connections to the natural world	D = Moderate use (25-49% of classes)
5. mixture of breadth and depth in coverage	E = Occasional use (0-24% of classes)

6. interesting and intellectually involving concepts
7. critical thinking about current events
8. practical applications to students' own lives
9. effective interactions among students

10. opportunities to collect pertinent information
11. opportunities to organize information
12. opportunities to analyze information
13. opportunities to communicate conclusions and ideas
14. ethical and social implications in the world
15. assessment of student performance in different ways

Please use the 5-point rating scale on the right for items 16-30 as you assess the value of these course characteristics to help you learn math and/or science content.

To what degree are these course characteristics important in helping you learn in this course?

16. active student learning	A = Very Important
17. up-to-date teaching technologies	B = Important
18. connections to other related disciplines	C = Unimportant
19. connections to the natural world	D = Detrimental to your learning
20. mixture of breadth and depth in coverage	E = Not Applicable or No Opinion
21. interesting and intellectually involving concepts	
22. critical thinking about current events	
23. practical applications to students' own lives	
24. effective interactions among students	
25. opportunities to collect pertinent information	
26. opportunities to organize information	
27. opportunities to analyze information	
28. opportunities to communicate conclusions and ideas	
29. ethical and social implications in the world	
30. assessment of student performance in different ways	

<u>Biographical Information</u>

31. What was your academic classification at the beginning of the Fall 2002 semester?
A= Freshman B = Sophomore C = Junior D = Senior E = Graduate or Unclassified

32. Do you plan to become certified to teach? [If unsure of the grade level, mark all of those that might apply.]

A= No, B = Yes, grades K-5, C= Yes, grades 6-8, D = Yes, grades 9-12, E= Undecided

If you are planning to teach, please also answer questions 33 to 35.
Use the 4-point scale on the right to indicate your opinion about each of these statements:

33. This course experience increased my motivation to try a variety of mathematics/science teaching strategies in my own teaching.
34. This course experience increased my understanding of how to use different mathematics/science teaching strategies.
35. I will likely share teaching ideas from this course with classmates.

A = Strongly Agree
B = Agree
C = Disagree
D = Strongly Disagree