REFORM OF PRESERVICE SCIENCE EDUCATION: AN EXAMPLE FROM A STATE-SUPPORTED UNIVERSITY

R. H. ADAMS and G. L. STRINGER
Northeast Louisiana University
Monroe, LA 71209-0280
e-mail: edadams@alpha.nlu.edu
gestringer@alpha.nlu.edu

The ongoing movement to reform the teaching and learning of mathematics and science began as an effort targeting grades K-12. This movement, however, also has significant implications for institutions of higher education, especially in the area of teacher preparation. Northeast Louisiana University has utilized an extensive system of support, including vital National Science Foundation funding, to redesign its science curriculum for elementary education majors. Four courses featuring the content areas of biology, chemistry, geosciences, and physics and integrated with respect to content and methodology were collaboratively developed by education and science faculty and were approved as requirements for all preservice majors. Preliminary evaluation results with respect to students' content knowledge and attitude are favorable. Ongoing efforts include the development of activities designed to further integrate the courses with respect to content and the execution of focused evaluative studies to reflect the degree of implementation of the reform practices that have been modeled by the university faculty.

Introduction and Background

The last ten years have witnessed some monumental changes in science and mathematics teaching at the university and precollege level [1]. These modifications have been directed by landmark efforts such as *Science for All Americans* [2], *Professional Standards for Teaching Mathematics* [3], *Benchmarks for Science Literacy* [4], and the *National Science Education Standards* [5]. Changes also have been guided by reform projects in specific disciplines such as *Earth Science Education for the 21st Century: A Planning Guide* [6] and *Earth Science Content Guidelines Grades K-12* [7] in the geosciences [8][9]. Other disciplines in the sciences, such as biology, chemistry, and physics also have developed similar reform-based standards at various levels.

The *National Science Education Standards* and other reform projects were initially

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developed with the intent of reforming the teaching and learning of science at the K-12 level. However, these documents also have significant implications for higher education, especially in the area of teacher preparation. This study investigates the response of Northeast Louisiana University (NLU) to reform initiatives and documents the nature, extent, and impact of the reform efforts in preservice education.

Northeast Louisiana University is a state-assisted, multipurpose, senior institution of higher education. It is located in Monroe, Louisiana, and serves a geographic region consisting of 13 parishes, the largest such region served by any institution of higher learning in Louisiana. Included in this region are 187 public schools and 20 non-public schools. They serve a student population of 173,000 with 4,000 teachers; the student population is composed of 47% minority and 53% non-minority. From this student population NLU draws 64% of its 11,000 students. The primary purposes of NLU are instruction, research, and service, the most compelling of which is instruction. Degree programs are offered in business administration, education, liberal arts, pharmacy and health sciences, and pure and applied sciences.

University Response to Reform-based Initiatives

Systemic reform in K-12 science will be inefficient and possibly even futile if not accompanied by simultaneous reform in teacher education. Northeast Louisiana University has been one of the leaders in Louisiana in developing, teaching, and implementing reform-based instruction at the university and precollege levels. Oliver and Loftin [10] found in a statewide study of the National Science Foundation's Collaboratives for Excellence in Teacher Preparation (CETP) program in Louisiana that "the progress of collaboration for reform has been most successful" at NLU and that by far "the most successful collaboration between the disciplines and education" was at NLU. Contributing factors to the success of NLU's systemic reform efforts were noted as joint appointments between the science disciplines and education and the consistent support of administration at all levels. Northeast presently has two joint appointments between the College of Pure and Applied Sciences and the College of Education (one in the geosciences and one in mathematics).

Major systemic reform endeavors in science and mathematics at NLU have been funded primarily by external grants which have totaled over $2.5 million in the last five years.

Principal funding agencies for the reform projects include the National Science Foundation (NSF), the Louisiana Systemic Initiatives Program (LaSIP), the Louisiana Collaborative for Excellence in the Preparation of Teachers (LaCEPT), the Louisiana Networking Infrastructure for Education (LaNIE), the Riverwood Educational Challenge Fund, and the Louisiana Applied Oil Spill Research and Development Program. A key to the systemic reform of the teacher preparation programs at NLU has been the diversity and extent of the projects. These projects have had a tremendous impact on restructuring science and mathematics instruction both at the university and at the precollege level.

The major impetus for reform in teacher education at the university level in Louisiana was the National Science Foundation's CETP. In 1993 the state of Louisiana, through its Board of Regents, the statewide coordinating board for higher education, received one of three CETP awards in its first cycle of funding. The state project is called the Louisiana Collaborative for Excellence in the Preparation of Teachers or LaCEPT. The purposes of the program are described in the NSF program solicitation and include making all students scientifically literate in a technological society, reforming the content and delivery of K-12 mathematics and science, preparing new teachers to meet the challenges of reform-based education, and engaging in collaborative efforts in order to bring about the desired changes.

The five-year award from the National Science Foundation is $4.5 million, and the state provides a matching $2.75 million over five years. All Louisiana public and independent colleges that prepare mathematics and science teachers are eligible to submit a proposal for a Campus Renewal Project (CRP). Through these proposals faculty and administrators evaluate the current status of reform on individual campuses, indicate their long-range vision to cultivate and institutionalize reforms, develop project activities to achieve the vision, and indicate plans for evaluation and dissemination of project work. Project proposers are encouraged to collaborate with other universities and to utilize other funding programs that can interface with the Campus Renewal Projects. Intracampus collaboration is required as is collaboration with local education agencies.

Emphasis on science reform actually occurred during the second phase of the NLU Campus Renewal Project. The initial target for reform in preservice education was the mathematical preparation of elementary education majors. Using the standards documents of the National Council of Teachers of Mathematics and The Mathematical Association of

America, mathematics and education faculty developed reform-based approaches for teaching existing courses required of preservice majors. Even though the second and third years of CRP funding witnessed the shifting of emphasis to science reform, preservice course offerings in mathematics continued to evolve. In Louisiana, state requirements declare that majors in elementary education must take 12 hours of mathematics as part of their course of study, but it is left to individual institutions of higher education to establish the content of their course offerings. During the 1997-1998 academic year, the mathematics course offerings and requirements for NLU elementary education majors were redesigned to include two new courses specifically designed for elementary education majors. Combined with an existing geometry course for preservice majors, the mathematics department now offers nine hours of courses tailored to the needs of future elementary teachers; the fourth course requirement is an introductory offering required of majors in various fields of study.

Revision of Preservice Education in the Sciences

In order to accomplish the objectives of national science standards in teacher preparation, there is a need for a broad background in the biological, physical, chemical, and geological sciences for K-8 teachers. To achieve this base of understanding, preservice teachers should understand the nature, role, skills, and processes of scientific inquiry as well as understand the essential concepts in the major science disciplines. Additionally, teachers need to understand and make conceptual connections in science and mathematics and utilize science in societal issues [5].

A 1994 study of preservice majors at NLU indicated that they were not receiving the necessary background in the sciences. In fact, records indicated that during the spring of 1994 53% of preservice majors were enrolled in a biology course, 36% in a geosciences course, 11% in a physical science course (primarily physics and astronomy), and 0% in a chemistry course. These figures were representative of the fact that for their required 15 hours in science most elementary education majors selected courses from the areas of biology and geosciences and excluded physics and chemistry courses.

The integrated science curriculum was designed and implemented at NLU to assist preservice teachers in achieving the "base of understanding that all teachers should have" according to the *National Science Education Standards* [5]. The development team for the

courses consisted of faculty from each of the specific science content disciplines (biology, chemistry, geosciences, physics) as well as science and mathematics educators representing elementary and secondary education. Fortunately, there were several faculty members who had been involved in reform-based programs in the sciences and mathematics. These individuals were eager to be a part of the reform process and assumed leadership roles in the project. There were not, however, similarly-experienced faculty in all science disciplines. In order to field a complete team, faculty representing some of the content areas had to be recruited into service and trained in reform-based strategies. Only with broad-based administrative support was this feat achieved. Faculty training and support activities included renowned guest speakers such as John Carpenter in earth science and Lillian McDermott in physics education, workshops related to reform-based classroom strategies such as the use of technology and alternative assessment, travel to appropriate conferences, and team discussion of pertinent journal articles related to the reform movement.

Weekly sessions in which the framework for the integrated science curriculum was collaboratively formulated were conducted during the fall semester of 1994 and the spring semester of 1995. The four courses, each a three-hour credit course meeting 150 minutes per week, received the approval of all university curriculum committees and were included in the university catalog as requirements for incoming freshmen preservice majors in the fall of 1995. The reform-based experience of the faculty involved in developing the integrated courses determined the order in which they were field tested. Faculty from the departments of physics and geosciences had directed reform-based projects for area teachers, so their courses were selected as the initial offerings for NLU students. The integrated physics and geosciences courses were taught in the fall of 1995, and the integrated biology and chemistry courses were offered the following spring.

Essential concepts and fundamental knowledge provide the basis for the integrated science curriculum for preservice teachers. Scientific inquiry through a variety of instructional methods is emphasized. Deliberate connections to mathematics and environmental issues are incorporated into all of the courses through the commonly shared themes of science, technology, and society. The following is a brief description of the integrated science courses:

- Integrated Biological Sciences emphasizes basic concepts and principles of the biological

sciences. These concepts and principles include the history and methods of biological science, basic chemistry and physiology of living systems, ecological principles and related environmental issues, and biodiversity.

- Integrated Chemistry emphasizes fundamental concepts of chemistry with an emphasis on the interdisciplinary nature of the concepts introduced. These concepts include atomic structure, elements and the periodic table, compounds and chemical change, water and solutions, organic chemistry, and nuclear reactions.

- Integrated Geosciences emphasizes an integrated approach to essential concepts in introductory geology (physical and historical geology), astronomy (from an earth science perspective), and weather to make clear personal applications of science, process skills, problem solving, and inquiry learning.

- Integrated Physics emphasizes the basic concepts and principles of physics, including force, motion, energy, light, heat, electricity, and magnetism. Personal applications of science, process skills, problem solving, and inquiry learning are also emphasized.

The major topics for the integrated science courses were chosen using several criteria. Since the audience for the integrated courses was perspective elementary teachers, the standards from various K-12 science reform projects were carefully studied and scrutinized. Other considerations which were significant in the development of the integrated science courses included precollege textbooks, college textbooks, and interviews with faculty who taught introductory courses in the various science disciplines.

Accompanying the need for reform in content and methods of instructional delivery is the need for reform in assessment. Since new instructional techniques are often utilized in the integrated science courses, alternative methods of assessment are used to support and complement traditional grading methods. Authentic assessment (evaluation that truly matches the concepts that are learned and the method in which they were learned) is incorporated into the traditional grading techniques. Examples of alternative methods of assessing students include the use of concept maps, student demonstrations, and group and individual projects.

Another significant feature of the integrated science courses is the limited number of students who are admitted to each class section. In an effort to provide the best setting for preservice students to experience reform-based teaching and learning, class size for the integrated science courses has been restricted to a maximum of 30 students. This size favorably compares to that of an elementary classroom. Such a commitment of instructional resources is a further witness of the support offered by the administration of NLU for the reform and improvement of preservice teacher preparation.

It should be noted that the term "integrated sciences" has several meanings at NLU. First, the courses are integrated in that scientific content and pedagogical methodologies are taught and modeled in the four-course sequence. This addresses a major theme of the *National Science Education Standards* [5] which state, "Teachers need to be taught science in college in the same way they themselves will teach it in school." Second, the integrated courses often cover and investigate topics from several different existing courses. For example, the integrated geosciences course includes concepts from physical geology, historical geology, planetary geology, oceanography, and atmospheric science. However, each course is offered through and taught in the science department whose name the course bears. That is, the integrated chemistry course is taught in the chemistry department; the biology course is taught in the biology department, etc. In addition, the laboratory component of the courses is integrated with the lecture component. Laboratory experiences in which students actively engage in hands-on/minds-on activities are conducted in conjunction with the other instructional techniques utilized to convey to students the concepts and principles included in the integrated courses. Finally, the integrated science courses are connected by a common theme of science, technology, and society.

Impact of the Reform of the Preservice Science Offerings

At this stage of development and evaluation, the comprehensive impact of the integrated science courses is not clear. However, preliminary results look very promising. For example, attitude surveys administered in the integrated geosciences course since the fall of 1995 have averaged 1.6 on a scale ranging from -2 to +2 with -2 being the most negative response and +2 being the most positive. Students scores on pre- and post-tests based on concepts and principles taken from major science reform efforts have shown an average increase of 49% from pretest to posttest results. Further, posttest scores by students in traditional courses

were 40 percentage points less than those of students in the reform-based course. Additional studies and interviews with inservice teachers who participated in the four-course sequence will more clearly reveal the degree of success that can be claimed.

Ongoing Improvements

Course developers felt great satisfaction with the adoption of the integrated science courses as requirements for all preservice elementary education majors. The institutionalization of the courses by the university signaled the accomplishment of a significant milestone for proponents of reform-based teaching in the realm of higher education. It was the case, however, that the faculty involved in the development and teaching of the curriculum wanted to improve the courses and offer the preservice students an insight into the integration of the scientific content areas. That is, they wanted to model for the students examples of the connections between chemistry and physics or chemistry and biology or biology and geosciences. This desire led to the development of multidisciplinary experiments which focus on one scientific content area but feature the connections among other areas. For example, one of the experiments is, "What in the World is an Otolith and How is it Used in Paleontology?" This experiment has as its primary content area geosciences, but it includes exercises that make deliberate connections to chemistry and biology. Another experiment, "Pond in a Jar," is based on biology content but includes chemistry, geosciences, and physics. The intent of those developing the experiments was to make them ongoing throughout the four-course sequence and to emphasize in a specific course the content that is pertinent to that course. In addition, the experiments will be revisited, and further societal and personal implications will be emphasized when, as seniors, the students take their education methods courses. Following the successful completion of their methods courses, the preservice teachers will enter the classroom as student teachers. Since the experiments have been developed around essential scientific concepts that are appropriate for the K-8 classroom, the opportunity to review and expand upon applications of the experiments will be of great benefit to these soon-to-be classroom teachers.

Conclusions and Recommendations

A key component in determining the success of the newly-developed curriculum is the degree of dissemination of the concepts and the methods taught in the integrated science courses. That is, are those beginning teachers who were impacted by the new curriculum

implementing reform-based strategies in their classrooms? Further, how much support do these novice teachers need to be able to implement reform methodologies? Finally, how can improvements be made to better prepare current preservice teachers in reform-based instruction? Studies are being planned to answer the above-mentioned questions. Information about the degree of implementation and attitude toward teaching science using reform strategies will be collected in the form of surveys and interviews. Plans are underway to offer assistance and additional ideas to beginning teachers through a web site supported by a network consisting of university faculty and experienced inservice teachers who were participants in an NLU-directed and NSF-funded program. Requests for assistance will offer insight to university faculty regarding areas of strength and weakness and will provide guidance for further improvements in the teacher preparation program.

National Science Foundation funding is scheduled to terminate at the end of 1998. That will not, however, signal the termination of the work described in this article. True systemic reform can be achieved only through the collaborative efforts of all involved. Administrative support, university-wide collaboration, and excellent relationships with local education agencies are well-established factors that have contributed to the degree of success attained thus far. These, too, are the factors that will sustain and nurture the ongoing efforts to improve the teaching and learning of science from kindergarten through higher education. ■

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