

PARTNERSHIP BETWEEN UNIVERSITY AND MIDDLE SCHOOLS: AN APPROACH TO STRENGTHEN MIDDLE SCHOOL MATHEMATICS AND SCIENCE EDUCATION

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ABSTRACT

This paper discusses a partnership between a university and middle schools to strengthen the mathematics and physical science education. Through the partnership, two summer institutes were organized by the university for teachers from local schools. The institutes introduced certain selected engineering problems and engineering design methods to illustrate the application aspect and the integrative nature of mathematics and science, and familiarized teachers with engineering problem-solving/design techniques. Such experience was designed to broaden teachers' scope of learning, provided them the background knowledge to develop an interdisciplinary approach to teach mathematics and science, and made subject contents more interesting and stimulating to middle school students. Moreover, the design experience also helped teachers develop a project-oriented, hands-on approach to foster students' ability in problem solving and lifelong learning.

INTRODUCTION

The shift from an industrial to information society in the U.S. called for reforms in mathematics and science education. Two new education standards, the National Science standards [1] and the National Mathematics Standards [2], were proposed by the National Research Council (NSC) and the National Council of Teachers of Mathematics (NCTM), respectively. These new standards emphasize nurturing students' ability in problem-solving and lifelong learning, thus to enable them to integrate mathematics and science with technology to solve real-world problems. Implementation of these goals requires mathematics and science teachers to develop new curriculum and approaches. This has presented a great challenge to teachers, especially to those working in rural school districts. Compared with their counterparts in urban schools, rural school teachers usually work in a more isolated environment, and have less financial resources and opportunity to conduct professional development. As such, it is more difficult for them to implement the new standards.

To implement the new standards, mathematics and science teachers of rural schools need assistance in the following areas: (1) appropriate education materials to stimulate and challenge students; (2) strategies to enhance problem-solving ability in students; (3) means to conduct inquiry teaching; and (4) ways to foster cooperation between mathematics and science education. Engineering and education faculty at the University of Wisconsin-Platteville had conceived an approach and a plan to address the above needs and to foster teachers' professional development. As pointed out in a recent report by the National Commission on Mathematics and Science Teaching for the 21st Century [3], teachers' competence is pivotal for improving quality of education in U.S. schools. One of the seven recommended strategies from that report says: "Summer Institute must be established to address the professional development needs...". To echo such a recommendation, we sought and received support from the Eisenhower Grant to carry out our plan.

The University of Wisconsin-Platteville is a small teaching institution with approximately 5,800 students and offers forty majors, and is located at the center of a rural area with no major industrial center within a radius of at least 100 miles. Among these majors there are four engineering programs accredited by the Accreditation Board for Engineering and Technology, and an education school accredited by the National Commission for the Accreditation of Teacher Education. The geographical location of the University, together with its expertise in engineering and education, creates an ideal situation to implement the proposed program. Our team included faculty from mechanical engineering and education programs, and a master teacher from a local school. The responsibility of the engineering faculty was to teach the content material while that of the education faculty was to take care of pedagogy issues. The master teacher served as a tutor and a facilitator to help teachers learn concepts and worked with them in developing curriculum.

PROGRAM OBJECTIVES

The primary objective of this proposed program was to enhance mathematics, physical science, and technology literacy of experienced teachers, and thus to empower them to affect a reform advocated by both the NSF and NCTM in their school districts. Specific objectives are to deepen and broaden teachers' scope of learning in mathematics and science subjects through application, to familiarize teachers with engineering problem-solving techniques that are effective in solving open-ended problems, to provide teachers a holistic view of mathematics and science to minimize rigid boundaries between the two disciplines, and to promote

cooperation between mathematics and science teachers and enable them to develop an integrative approach to supplement their teaching in middle schools.

WORK PLAN

Each summer institute was conducted in two sessions over two consecutive years. Each session lasted for four weeks. The first three weeks focused on learning content materials, and the remaining one week was for participants to make plans for implementation. Each week consisted of thirty hours of intensive learning activities. Approximately thirty middle school teachers from public and private schools in local and neighboring school districts were invited to participate.

(A) Instructional Methods:

The proposed institute used the problem-based learning (PBL) [4] as the instructional method. To initiate this learning, a problem situation was created to drive the learning activity on a need-to-know basis. In other words, a problem/design project related to an intended subject was presented to participants at the outset of a class so that participants could identify what they needed to know in order to solve the problem. After prioritizing their learning needs, teachers were to gather knowledge from collaborative learning, lectures, and laboratory activities at the institute. Then they would apply the knowledge to solve the design project [5].

Daily activities in the institute would consist of the following three interrelated components:

- 1) Lectures: The purpose was to provide the background knowledge for conducting engineering design, and illustrate how mathematics and science are used to solve real world problems.
- 2) Experiments: Participants were to conduct an inquiry-based learning that combined observation with hands-on activities. Some commonly available devices were used as the experimental objects to learn how mathematics and science were involved in making these devices. This type of experiments did not require expensive equipment and can easily be carried out in rural schools.
- 3) Design: Participants worked in teams to accomplish two tasks. The first task was to work on design projects, and the second was to develop strategies for implementation of what they have learned in classroom teaching. To accomplish the first task, an engineering problem-solving process [5] was used to guide the design work. This process included problem identification, analysis, design, construction of physical models/prototypes, and testing. For the second task,

participants developed materials and plans to incorporate what they learned in the institute into their classroom teaching.

B) Curriculum Materials

To implement PBL, participants focused on six topics – three were covered in the first session, and the remaining three in the second session. Criteria for choosing these topics were: (i) they must be interesting and closely related to students' life experiences, (ii) they would require the integrative knowledge of mathematics and science to solve, and (iii) they should match the level and educational objectives of secondary schools specified in the NCTM's standards and the National Science Standards. The following is a brief description of these topics.

1) Simple Machines. The objectives of the topic are to demonstrate how machines are built from simple machines and how principles of physics and mathematics are involved in the design. The learning was initiated from a research project entitled "Why Bicycle is the Most Efficient Transportation Machine". Several types of bicycles were used as the physical models of the research. Focal points of the study were: anatomy of bicycles, calculation of resistance forces, mechanical advantage of various components, and design parameters relevant to the performance (braking, power, speed, and safety) of bicycles.

2) Motion of Projectiles. This project involved the design and building of a projectile launcher to illustrate the concept of velocity and acceleration, and Newton's laws of motion. Here PBL was implemented through designing and building a catapult that would launch a golf ball to the farthest possible distance from a given set of materials. The work included using governing mathematics and physics principles to identify the important design parameters, building the device in accordance to their design, and conducting testing to verify their analysis.

3) Physics of Bungee Jumping. The purpose of this project was to illustrate how to develop a mathematical model to solve a physical problem. Participants were asked to design and make a bungee cord with rubber bands that would allow a bungee jumper (a barbie doll in this case) to come as close to the ground as possible (without hitting the ground, of course) after it was released from a given height. The design work included: (i) developing mathematical equations from physical laws, (ii) measuring relevant physical properties of rubber bands, and (iii) calculating the required cord length. To conclude the study, a test was run to verify the validity of the analysis.

4) Design of Structures. The purpose of this project was to apply mathematics and physics, appropriate computer software, and creativity to the design of a structure. The assignment is to design and build a model truss bridge from a given set of materials. The bridge is designed to carry a certain load, span a given distance, and weigh as little as possible. The bridge design includes: (i) selection of geometrical forms of the truss, (ii) calculation of load in each truss member, and (iii) determination of the required cross sectional area of truss members. This task requires the use of trigonometry, algebra, equilibrium equations, and physical properties of materials. A software program "West Point Bridge Designer" [6] was used to facilitate the analysis. This software is specially designed for high school projects and can be downloaded from the Internet. Based on the analysis, a model bridge was built for destructive testing. Causes of failure were analyzed by the participants.

5) Design of Model Airplanes. With this project, participants learned the physics of flight from the design and construction of a rubber-band-driven airplane. Relevant subjects such as fluid pressure, Bernoulli's principle, and lift and drag forces are treated. Using lift and drag forces as a guide, participants first identified the relevant design parameters. Then they designed and built two model planes, one for longest flying distance and the other for longest duration of flight, by varying those design parameters. A contest was run among design teams.

6) Model Windmill. This project was to design and construct a rotor of a windmill that would produce maximum power from a given wind speed. It covered the following subject areas: (i) wind as a form of renewable energy, (ii) power and efficiency of an energy system, (iii) measurement of wind speed, torque, and power, and (iv) design parameter related to rotor performance. Participants first learned how to develop a simple test stand for measuring torque and speed of a windmill. Then they varied parameters such as blade angle, blade width, and blade diameter in their design, and used the test stand to evaluate their performance.

C) Development of Curriculum for Implementation

In the fourth week of each session, participants developed strategies and supplementary curriculum materials suitable for use in middle school mathematics and science education. Under the guidance of education and engineering faculty, teachers worked in teams to study pedagogical techniques based on material learned in the previous three weeks, and explored effective methods to infuse an integrative approach to teach mathematics and science. The

study of pedagogical techniques focused on (i) how to create an environment for project-based learning, (ii) how to identify a good project, and (iii) how to guide students through this type of learning. At the conclusion of each session, teachers were required to submit a plan for implementation. The content and pedagogical learning experience would enable teacher to envision ways to tailor the content to suit his/her teaching style. This approach provided flexibility for teachers to customize the method in accordance with their needs.

METHODS FOR EVALUATION AND DISSEMINATION

The program had undergone two types of evaluation. The first type was to evaluate each course while the course was being taught and the second type was to evaluate the impact of the project after its completion. With the purpose of improving the quality of instruction, the first type of evaluation was conducted internally. Questionnaires were distributed among participants to evaluate the quality of course contents and instructional methodology, and the usefulness of the handout materials. The evaluation was conducted midway through the course and at the conclusion of the course. The second type was to evaluate the merit and value of the project. Through reports submitted by participants and on-site observation by the consultants, the program impact on classroom education and follow-up implementation of the program were assessed. Questionnaires were distributed to school principals and district school administrators to evaluate the effectiveness and impact of the program.

The Internet was used as a tool in two ways to disseminate information. It was used to set up a bulletin board that served as a forum for discussing problems and ideas about the proposed approaches. Second, it was used to develop a web-based repository for disseminating educational materials. This allowed teachers to access the repository to learn new developments in mathematics and science education.

CLOSURE

Both summer institutes were a complete success. Participants went back to their schools with many ideas and educational materials developed in the institutes. Based on these materials, teachers developed more than forty teaching units which were posted on Blackboard for reference. Many of the participants had shared their learning experience with their colleagues and played a leadership role in developing new approaches and curriculum in their school districts. In an assessment conducted by a team of educators, we concluded that the institutes had a positive impact on students, teachers, and schools.

REFERENCES

1. National Research Council, "National Science Education Standards", National Academic Press, 1996.
2. National Council of Teachers of Mathematics, "Curriculum and Evaluation Standards for School Mathematics", 1989.
3. National Commission on Mathematics and Science Teaching for the 21st Century, "Before It's Too Late", 2000.
4. Vicky Hendley, "Let Problems Drive The Learning", ASEE Prism, Oct., 1996.
5. Muller, C. B. et al., "Engineering Concepts in the High School Classroom: The Dartmouth/Thayer Problem-Solving Methods", Proc. ASEE/IEEE Frontiers in Education, 1995.

BIOGRAPHY

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