Modeling Assessments of Innovative Physics Courses

Symposium Overview

Robert Fuller, Leslie Wessman & Graham Dettrick
Professor Emeritus, Physics Education Research, Univ. of Nebraska Lincoln Nebraska USA
Professor Emerita, Teacher Education, Hope College Holland Michigan USA
Professor Emeritus, Science Education, Monash University. Gippsland, Victoria, Australia

Response by:
Frits Gravenberch,
Acting President, Netherlands Association for Education in Natural Sciences (NVON), The Netherlands

An innovative calculus-based university physics course was evaluated using a mixed methods action research(MMAR) model. A brief discussion of the characteristics of the experimental physics course and control course are given. The main focus of the symposium will be on the attributes of the MMAR model. The model includes qualitative and quantitative aspects. An overview of the MMAR model is presented and the interview protocols used in the pre, mid-term, and post interviews of students and instructors of the experimental course are discussed. The written questionnaires used to assess students' and instructors' pre-post attitudes toward science (physics) and technology, their preferred approach/model for teaching/learning physics, and their particular orientation to the nature of science are presented. An explanation of how the personal interviews and quantitative questionnaires enhance the research design will be given.

In response, Mr. F. Gravenberch, NVON Acting President, The Netherlands, compares the MMAR evaluation to results of 'similar' projects that were conducted in the Netherlands and comments on teachers' expectations of outcomes of projects in curriculum development.

The presentations are available on the website: http://www.hope.edu/GIREP2006.

INTRODUCTION

Two experimental sections of university calculus-based general physics sections were offered using The Physics InfoMall CD-ROM, Excel, word-processing, and electronic communication technology to see if technology could be used to enhance the learning of physics. It was anticipated that the experimental physics sections would help faculty and students focus on addressing ill-defined problems from the natural world.

Calculus-based Physics(CBP) Program

The department expectation was that the experimental sections would follow the same course content and goals as the regular general physics classes, and take the same final exam. The regular physics course is a rigorously controlled, competently organized and presented program designed to achieve a high level of mastery in reproducible physics knowledge (i.e., facts, laws, theory), and the utilization of this knowledge in the solution of standard undergraduate physics problems and applications. These regular students are expected to know and reproduce stereotypic "theoretical" and "conformational" physics approaches supported by a traditional text where the outcome of such instruction could be expected to have not much more than a routine application within a clearly identified occupational context.

Student Population

During the semester of the study, approximately 540 students took first-year physics. These freshman students were regarded by faculty as being "highly motivated" and having "strong math skills." Two sections of 24 students each were created on the basis of positive responses to an E-mail request for volunteers. A deliberate attempt was made to include women and minority groups in the experimental sections. "Control" sections were selected for comparison with the "experimental" sections by matching instructors in the regular sections with those in the experimental sections as well as possible. Five sections were chosen as control groups.

Electronic Resources

Students in the two experimental sections worked in groups of two through four using physics laboratory PCs running under Windows fitted with a CD-ROM drive. The hardware was up-to-date and the software was the most modern available. While students in all sections had access to the campus E-mail facility, the experimental sections began with a special electronic conferencing capability. Use of the electronic communication tools, Excel spreadsheet software, and the Word pad available in the InfoMall CD-ROM had a deliberate emphasis in teaching and learning.

While the experimental physics syllabus content objectives were the same as the control sections, the experimental activities were constructed so that students had opportunities to make maximum use of the CD-ROM's research potential and its capacity to aid unique, diverse, and generalizable approaches to problem solving. It was anticipated that concept learning and depth of understanding could be facilitated through the wide range of materials that students could have addressed to meet their personal learning needs.

In addition, these computer-based learning activities were intended to encourage more autonomy and cooperative effort in learners. In so doing, the instructors set up a situation of potential conflict with students' past experiences and associated attitudes and values around the teaching and learning of physics.

Research Design

Since an important component of the experimental project was to be the development of model instructional strategies and activities for the use of the CD-ROM, it was agreed that a mixed methods action research model would be used to evaluate the experimental program. Pre/post tests were used to measure aspects of growth; summative tests and exams were used to measure mastery of syllabus content and applications. Pre- and post-tests included Nature of Science Profile (NOSP) (Nott & Wellington, 1993), Strategies in Teaching Physics (SITP) (Dettrick, 1995), Attitude to Science/Physics (ATP) (Dettrick, 1988), and the Force Concept Inventory (FCI) (Hestenes, Wells & Swackhamer, 1992).

Student interviews and reflective student diaries paid particular attention to the functionality of teaching and learning with the CD-ROM. They provided a database which was used periodically to inform instructional staff about strengths and weaknesses of the CD-ROM as an instructional tool and the most effective means for its utilization in teaching physics. Staff notes of the process of progressive change throughout the semester were used to inform and document the action research.

Initial analysis of the data permitted observations about 1) diversity of beliefs and attitudes in both students and instructors, 2) changes in perception about the nature of science and about preferred teaching/learning strategies, 3) changes in attitude toward physics learning, 4) the advantages and disadvantages of the use of the CD-ROM as perceived by instructional staff and students, 5) descriptions of special skills developed in electronic information retrieval and application in problem solving, and 6) the use of electronic tools for individual and group work. Researchers also reflected on the institution's desired educational outcomes in relationship to the initial vision and culminating experiences in the experimental sections.

CURRICULUM CHANGE

Approach to Teaching

Lecture time which typically is devoted to the delivery of subject content was deliberately set aside in favor of activities that were designed to facilitate the development of broader professional skills grounded in critical thinking and problem solving. The major changes that the project instructors designed and implemented included:

- ✓ requiring inventive problem solving with respect to complex situations which had ill-defined approaches and unclear solutions
- ✓ deluging students with relevant and irrelevant information which required analysis, criticism, and synthesis.
- ✓ modeling conditions met by human beings in the real world rather than work within an abstracted or generalized framework modified to ease instruction and simplify learning.
- ✓ encouraging scholarly research using the CD-ROM resources.
- ✓ planning for individualized problem solving.
- ✓ requiring learner creation of problems to be solved by peers.

Students' Perceptions of the Experimental Process

Over the semester students in the experimental sections reported experiences and attitudes which represented several recurring themes:

- ✓ negative impact of time constraints
- ✓ confusion in choice-making activities
- ✓ problems working with others toward a common goal
- ✓ concern about preparation for assessment
- ✓ technology as a tool for studying physics added unwanted complexity

Attitudes among Instructors

The teaching/learning curriculum in CBP at this institution is structured in such a way that it appears that instructors teach homogeneously and students learn homogeneously against a homogeneous experience base. Nothing could be further from the truth. The instructional staff involved in this project represent a diversity in professional experience, preparation, personal philosophies and personality profiles.

The "Attitude to Physics" profile showed that the experimental class instructors were not significantly different from the control groups' instructors in their attitudes.

The desired institutional outcomes include phrases like *exploring contradictions between personal assumptions and evidence*, *framing ill-defined problems*, and *intellectual curiosity*. Such outcomes appear to go hand-in-hand with an approach to instruction which requires the student to be personally involved in investigations or inquiries and consideration of the outcomes of those investigations. Subtest scores indicate that some instructors' attitudes were weakly disposed towards personal inquiry in physics. "Adoption of Scientific Attitude" and "Disposition to Practical, Hands-on Involvement" were the two sub-tests where the strongest differences between instructors occurred. The Attitude to E-technology demonstrated the greatest range of diversity among the instructors. Some of the instructor responses indicate slightly negative responses. What the instructors felt and saw themselves doing normally in physics teaching was not aligned with the aspirations they had for the attitudes and actions of the students they taught with respect to electronic communication technology.

Attitude toward Physics among Students

In examining the data from the Attitude to Physics survey instrument, the researchers began to elicit a picture of the students' adopted and often unexamined attitudes in three dimensions: 1) toward scientific inquiry in physics, 2) toward teaching/learning physics, 3) toward physics as a practical, hands-on activity. The way in which the ATP survey is constructed, a positive response to questions addressing teaching and learning issues in physics would indicate positive support for inquiry rather than a content, cultural-reproductive approach to physics. A content--or reproductive--approach to physics does not facilitate inquiry or critical thinking which is the real-life approach to problem solving, rather than the popularly-assumed computational problem-solving approach.

Considering the mean as a measure of central tendency, at the beginning of the semester the tendency of all seven project classes was toward vague to moderate support for an inquiry or activity-based approach to physics. The students may have adopted this position as a result of their previous high school experiences. In the scores from the post-tests, student support for a practical, inquiry, activity-based, hands-on program declined. The data collected from diaries and interviews support the observation that participative, inquiry-based physics programs increase the stress because of the demands associated with allocation of precious time.

As a result of the data analysis, researchers recommended that when instructors plan and innovate curriculum change in physics courses, they may wish to consider time constraint stresses that force students to make decisions that devalue academic enterprises. The effect of this constraint appears to reinforce traditional content-based, reproductive and rhetorical approaches to teaching physics. This is a contradiction to modern approaches to teaching science and to theories of cognitive development. Furthermore it mitigates against a research-based culture which one would expect in college physics programs.

On another dimension, researchers encouraged instructors to re-examine their views of RIGOR as not only associated with level of difficulty or the "covering" of masses of memorizable content to which students may be exposed. A recent definition (Strong, 2001) invites instructors to consider rigor as a curriculum goal: *Rigor is the goal of helping students* *develop the capacity to understand content that is complex, ambiguous, provocative, and personally or emotionally challenging.* Inquiry-based programs like the experimental sections make strong cognitive demands on students and force them into more exacting, subtle real-world decisions. The ability to manage difficult content should be a fundamental skill all students need both in school and out. It must be realized that both inquiry and rigor require time and flexibility that conflict strongly with the notion of "covering" a large quantity of syllabus material. Inquiry approaches to physics incorporate model building and revision based on feedback and the tentativeness of solutions. As in physics itself, there will always be the possibility for a more refined response.

If students are left to their own devices, cognitive, attitudinal, and behavioral change may occur gradually, in an evolutionary fashion--but this cannot be guaranteed. It is critical that the higher education experience offer multiple opportunities, beginning in the first year, to grow into and evolve an ever expanding and more sophisticated world view. This does not develop magically, or spontaneously at the moment of graduation. Learners must be given increasingly demanding academic situations in which to gain confidence and competence in examining individual situations, weighing the circumstances, supporting a position, and making decisions.

The Challenges of Innovation

There are few rewards or incentives for teaching which develops critical thinkers and problem solvers. Faculty are diverse individuals and must be given the richness of time and opportunity to discuss important issues with one another and come to consensus on a few critical dimensions:

1. articulate definitions of critical thinking and problem solving that will best serve the students and transfer to their professional lives.
2. determine how is it possible to assess critical thinking and problem solving and give students appropriate feedback so that they may grow in their depth and breadth of knowledge, in their skills, and in their positive attitudes and disposition toward physics.
3. determine what will be the overt rewards for doing critical thinking and for teaching critical thinking.
4. introduce progressive changes to the nature of the measurement of "success".

Deans and department chairs make a critical error if they assume that there is a single profile of the "best" physics teacher. As has always been the case, faculty will be diverse individuals. Entry-level training for new instructors will be critical in developing a strong teaching staff with a common commitment to the department goal. It is important to encourage a department or institutional norm which encourages collaboration, team problem-solving, and information and skills sharing on the use of ever-evolving technology that could be appropriate for the classroom setting.

BIBLIOGRAPHY

Dettrick, G. W., 1995: The Strategies in Teaching Physics (SITP) is an 80-item, 6-point Likert scale questionnaire which can be divided into 3 major sub-tests along the following dimensions: neo-classicism or “traditionalism”; liberal-progressivism; and social criticism, USAFA Project Report. Available in PDF form from the website.

Dettrick, G. W., 1988: The Attitude To Science/Physics (ATP) is an 87-item, 11 point Likert scale opinionaire which can be divided into seven sub-tests. The seven sub-tests measure each person's attitudes toward following aspects of physics: social implications of physics; scientific inquiry in physics; teaching/learning physics; physics as a personal threat; practical, hands-on involvement in physics; and socio-cultural value of physics, value of e-technology in physics. The ATP is a specifically designed extension of a 60 item 6 subtest Attitude to Science Questionnaire used as coursework material in Graduate Diploma of Education classes for Science Graduates training to be High School Science Teachers. Monash University, Gippsland Campus, 1988-1998. Available in PDF form from the website.

Hestenes, D., Wells, M. & Swackhamer, G., 1992: Force Concept Inventory, The Physics Teacher, Vol. 30, March, pp. 141-158.

Nott, M. & Wellington, J. 1993: Your nature of science profile - An activity for science teachers, School Science Review, Vol. 75 (270), pp. 109-112. The Nature of Science Profile (NOSP) is a 24-item, 11 point Likert scale questionnaire which can be divided into 5 sub-tests along the following dimensions: relativism < -- > positivism; inductivism < -- > deductivism; contextualism < -- > decontextualism; process < -- > content; and instrumentalism < -- > realism. Available in PDF form from the website.

Strong, R. W. Silver, H. F. and Perini, M. J., 2001: Teaching What Matters Most: Standards and Strategies for Raising Student Achievement, p. 7., Association for Supervision & Curriculum Development.