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ABSTRACT

This study was designed to investigate the effect on teachers and their students of a model of professional development that immerses teachers in scientific inquiry appropriate to their classrooms while modeling the use of reform-based pedagogical strategies for teaching science. The course was designed and team taught as a collaborative effort between scientists and science educators. Quantitative data were collected on teachers' pre and post course science content knowledge, attitudes toward science, and science process skills. Quantitative data on the process skills and attitudes toward science of students of project participants and matched groups of students and teachers not participating in the project were collected and compared. Qualitative data from open-ended questionnaires, journals, and learning logs were collected from both students and teachers. The program was found to have a statistically significant impact on teachers, their classrooms, and their students. It is recommended that future science professional development projects incorporate collaboration between scientists and science educators. These collaborative efforts should focus on integrating scientific investigations designed and carried out by participants with appropriate pedagogical models for incorporating inquiry-based learning in the classroom. Contains 16 references. (Author)

Experiencing Scientific Inquiry and Pedagogy: A Model for Inservice Training for Science Education Reform

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EXPERIENCING SCIENTIFIC INQUIRY AND PEDAGOGY: A MODEL FOR INSERVICE TRAINING FOR SCIENCE EDUCATION REFORM

Abstract

This study was designed to investigate the effect on teachers and their students of a model of professional development that immerses teachers in scientific inquiry appropriate to their classrooms while modeling the use of reform-based pedagogical strategies for teaching science. The course was designed and team taught as a collaborative effort between scientists and science educators. Quantitative data were collected on teachers' pre and post course science content knowledge, attitudes towards science, and science process skills. Quantitative data on the process skills and attitudes toward science of students of project participants and matched groups of students of teachers not participating in the project were collected and compared. Qualitative data from open-ended questionnaires, journals, and learning logs were collected from both students and teachers. The program was found to have a statistically significant impact on teachers, their classrooms, and their students. It is recommended that future science professional development projects incorporate collaboration between scientists and science educators. These collaborative efforts should focus on integrating scientific investigations designed and carried out by participants with appropriate pedagogical models for incorporating inquiry-based learning in the classroom.

Experiencing Scientific Inquiry and Pedagogy: A Model for Inservice Training for Science Education Reform

Nationwide the movement to reform science education is well underway. The publication of *The National Science Standards* (NRC, 1996), *The Benchmarks for Science Literacy* (AAAS, 1993), and *Scope, Sequence, and Coordination* (Pearsall, 1992) has provided blueprints for changes that, once implemented, should significantly improve student achievement in science. In order to successfully follow these blueprints, it is essential to have teachers who are knowledgeable of science content, confident of their ability to guide and conduct science investigations, and well-versed in the pedagogical skills necessary to lead inquiry-based, student-centered learning. Most of the elementary and middle-grades teachers currently teaching do not have a strong science knowledge base and have not been trained in the use of reform-based pedagogical approaches (AAAS, 1990). It is, therefore, essential that effective inservice models be developed that ensure that reform-based teaching strategies are implemented in classrooms.

Two different approaches to improving science instruction are currently popular. One approach involves placing selected teachers in the research laboratories of scientists who are actively involved in scientific research. Teachers work under the direction of the scientists to perform laboratory procedures, collect and analyze data, and participate in discussions of the meaning of the data (Fraser-Abder & Leonhardt, 1996). Although this approach allows teachers to develop an understanding of the process of basic scientific research, the laboratory techniques often cannot be transferred to the classroom. The researchers, who usually have no background in appropriate pedagogical techniques, may not be equipped to help teachers translate what they are doing in the laboratory into classroom appropriate strategies. An additional disadvantage of this approach is the small numbers of teachers who can be impacted.

In a second approach, groups of teachers participate in programs in which they experience hands-on activities which are often selected from one of a number of available nationally recognized programs. Appropriate pedagogical techniques for teaching hands-on science may be discussed and teachers receive training on how to incorporate hands-on science into their teaching. This approach is often successful in converting teachers to a more active science program in which students experience the activities developed in the program. However, this approach does not necessarily give the teacher a clear understanding of how scientific investigations are designed, performed, and analyzed. Teachers who experience this type of professional development can replicate activities, but are not able to guide students in true inquiry-based science.

This study was designed to combine the best of both approaches. The program was developed collaboratively by scientists and science educators to involve teachers in inservice training that utilized basic techniques of scientific research to pose and solve problems appropriate to the science classroom. The goal of the program was to immerse participants in the process of science and appropriate pedagogy by modeling instruction that incorporated both. This study is an account of the inservice training program, Project LIFE, *Laboratory Investigations and Field Experiences,* that sought to introduce middle grades life science teachers to science reform and equip them with the knowledge, skills, and confidence to change the way they were teaching. The effect of the program on the teachers and on the students in their classrooms was documented. The elements of the inservice program that led to its success were identified.

Project LIFE is in its fourth year of funding by the Louisiana State Systemic Initiatives Program (LaSIP) which is funded by the National Science Foundation, the Louisiana Board of Elementary and Secondary Education, and the Board of Regents. The project was designed by university science and science education faculty working closely with an exemplary middle grades teacher. The initial design was based on the staff's understanding of what constituted good science and good science teaching with input from teachers and public school administrators describing their perceived needs. During its lifetime the inservice model has been refined based on input from over 130 project teachers and on staff reflections throughout the process.

The foundation of the model of good science teaching presented by this inservice project is the constructivist philosophy, that individuals build their own knowledge by incorporating what they are learning into what they already know (von Glasersfeld, 1992; Matthews, 1992; Yager, 1991). In translating this philosophy into practice in the development of this inservice training, three aspects were addressed: learning from active engagement; learning based on personal experience, as students and as scientists; and learning by confronting previous understanding that is not in agreement with current scientific explanations (conceptual change teaching). (Stofflett, 1994; Stofflett & Stoddart, 1994)

Methodology

The Project LIFE program has four major components: a 3-week summer course; an independent science research project; academic year follow-up through workshops, classroom visits, and newsletters; and a Leadership Institute (second summer) for selected program participants. This paper will focus on the effect of the summer course and independent science research project on teachers' science content knowledge, science process skills, attitudes toward science, and classroom teaching behaviors. In addition, the process skills and attitude towards science of students of teachers who went through the program will be compared with those of students of teachers who did not go through the program.

Subjects

The target population was life science teachers in northern Louisiana with a focus on middle grades teachers. The participants included 34% upper elementary, 55% middle grades, 3% high school, and 8% teachers of multiple grades. Thirty teachers participated in the project each year, for a total of 90 participants. The sample was 88% female, 12% male; 79% white and 21% black. The years of teaching experience ranged from 1 year to 29 years with a mean of 10.7 years.

Treatment

The 3-week summer course was an intensive team-taught program that focused on integrating concepts from life/environmental science, chemistry, and mathematics. The instructional team consisted of a science educator, a biologist, a chemist, and an exemplary middle grades teacher who serves as the project site coordinator. All four were in the classroom throughout the course. During investigative activities the instructors circulated among groups of teachers. They modeled the role of teacher as facilitator as they asked probing questions that stimulated participants to problem solve by posing and testing possible solutions to their own questions.

Participants engaged in learning science and science process skills by experiencing the techniques they were asked to use with their students. Problem centered learning (Wheatley, 1991) was frequently used during the course. Course instructors described a situation that naturally generated a question that needed to be answered. Within their small groups participants explored, discussed, and explained their interpretations to each other, continuing until they reached a solution supported by the group.

Alternative, authentic assessment was integrated with instruction throughout the course. Participants experienced multiple assessment techniques as project staff modeled the use of card sorts, concept maps, projects, learning logs, journals, higher level questioning techniques, gallery walks, and performance assessments to monitor participant understanding. The use of science demonstrations to assess conceptual understanding was a technique developed by project staff that was used throughout the program (Radford, Ramsey, & Deese, 1995).

Functioning as scientists and writing about science were integral parts of the summer course. Throughout the course teachers acted as scientists as they were immersed in hypothesizing; designing experiments; and collecting, recording, and analyzing data. Each participant recorded daily observations of on-going experiments in a learning log that was reviewed each evening by project staff. The logs provided the staff opportunities to pose probing written questions to individual teachers that caused them to think more deeply about their observations as they provided a written response. The learning log also included teachers' responses to questions that asked them to apply their learning in a new situation or to make connections among science concepts through concept mapping, diagrammatic representations, graphing, or other graphic organizers.

During the 4 weeks following the summer course, participants designed and conducted an independent science investigation. At the end of the 4 weeks the results of the investigations were presented at a Science EXPO. Administrators, other teachers, and the public were invited to attend. Hand-outs that described their investigation were provided by each participant and made available to all who attend the EXPO. Participants often presented these science investigations at the state science teachers' association annual conference.

On-going support of participants was both financial and instructional. The project provided participants with $300 to be used to purchase science supplies necessary to implement reform teaching strategies. An additional $100 was provided by each school system to enable participants to purchase consumable materials and animals and plants for use in their classrooms. Academic year instructional support consisted of 5 day-long workshops, attendance at the state science teachers conference, multiple visits to each participant's classroom by the project site coordinator, and regular project newsletters.

Research Design

Data were collected using a variety of instruments: written tests, attitude surveys, journals, learning logs, portfolios, and observations by the instructors during the course and by the site coordinator in the teachers' classrooms. A quasi-experimental study was conducted to compare the science process skills ability and attitudes towards science of the students of the Project LIFE trained teachers with those of students of matched teachers who had not been trained in the project. The teachers were matched according to grade level, class ability level, and type of science taught. In most cases, a match could be found within the same school. If this was not possible, then a teacher from a comparable school in the same system was used. The first year of the project, all students of all Project LIFE teachers were tested. In subsequent years, students of a random sample of approximately 10 Project LIFE teachers and 10 matched teachers was used.

Instruments

Evaluation of the project employed a combination of quantitative instruments, observations by the instructors and site coordinator, and portfolios prepared by the participants showing implementation of the project in their classrooms. Special attention was paid to how the teachers incorporated "doing science" into their classrooms. Quantitative evaluation instruments were used to collect data on teacher science content knowledge, teacher and student knowledge of science process skills, and teacher and student attitudes towards science. Teacher science content knowledge was measured by pre and posttests of the life science content included in the course. This instrument was a 75-item multiple-choice test developed by the instructors similar to tests used in traditional university introductory biology classes. The KR-21 reliability of the test was .83.

Teacher process skills knowledge was measured by pre and posttests of science process skills using the Middle Grades Integrated Process Skills Test (MIPT) (Padilla & Cronin, 1986). This test was also used as a post treatment measure for comparing the process skills knowledge of the participants' students with that of students of matched teachers who did not participate in the project. Field tests of the MIPT with 1152 seventh grade science students have demonstrated its reliability (KR 20 = .89) and validity for use with middle grades students (Cronin & Padilla, 1986).

Teacher attitudes toward science were measured by a pre and post course attitude survey consisting of 25 Likert-type items having a 5-point scale (strongly disagree to strongly agree). Similarly, student attitudes towards science and science class were measured with a 20-item survey having a simplified scale of three choices (yes, no, or uncertain). A quasi-experimental design as in the above evaluation of process skills achievement was used to compare the attitudes of students of project trained teachers with students of non-project science teachers.

Participating teachers were required to keep portfolios of their implementation of the project in their classrooms during the school year. Portfolios included evidence in three categories: teacher work, student work, and attestations from others.

Results

Teacher data from each year were analyzed separately. For each year, teachers improved from precourse to postcourse in their science content knowledge, science process skills, and attitudes towards science. Results of measurements of attitudes and science process skills of students of Project LIFE teachers and students of matched teachers who had not received project training were compared. Analyses of variance statistical tests revealed statistically significant differences in favor of the students of Project LIFE teachers when compared to students of non-project teachers on both science process skills and science attitudes. Year 1 Science Attitudes: $F_{1,1259} = 176.60$, $p<.0001$; Science Process Skills: $F_{1,1231} = 6.52$, $p=.01$; Year 2 Science Attitudes: $F_{1,394} = 165.30$, $p<.0001$; Science Process Skills: $F_{1,394} = 51.13$, $p<.0001$; Year 3 Science Attitudes: $F_{1,463} = 152.80$, $p<.0001$; Science Process Skills: $F_{1,460} = 87.80$, $p<.0001$. The effect of the treatment was also calculated by dividing the difference between the experimental and control group means by the standard deviation of the control group scores. Student attitude effect sizes were 0.73, 1.1, and 1.2 for Years 1, 2, and 3, respectively. Student science process skills effect sizes were 0.15, 0.84, and 0.99.

The approach taken by this professional development project had a significant impact on science instruction in the classrooms of the participants. A team of outside evaluators employed by the state to conduct a case study of the project reported that "all teachers interviewed and all classes observed were using ideas, materials, and activities from Project LIFE." (McGee-Brown, 1995, *Impact*, p. 13.) Students were asked to contrast their experiences in science in the past with their experiences with their project-trained teacher during the current year. The most frequently mentioned differences were that they were conducting more experiments, science was more fun, and they were learning more science. (McGee-Brown, 1995, *Impact*, p. 15.) In their response to the survey questions students routinely used the language of science including hypotheses, scientific method, technology, safety rules, scientific instruments, observation, measurement, organization, comparison, data recording, mathematics, experiments, research, lab work, living organisms, habitat, problem-solving, and systems. Students wrote about the importance of working in collaborative groups and discussing scientific ideas. Students' responses made it clear that they thought they were learning science, actively engaged in science, and having fun doing science.

In the classrooms of Project LIFE teachers the case study ethnographer noted that teachers were very actively engaged in learning with students. The teachers worked with the students to guide them as they experimented and collected data. Students did not feel that they were performing steps to find an answer predetermined by the teacher, but rather felt they were engaged in a collaborative attempt to answer a question.

Teachers indicated that their project training activities, including group science experimentation, discussion of results, and individual science research projects, helped them learn a great deal more science content and gain confidence in teaching their students through inquiry-based science. They began to really understand science, which is a prerequisite to helping students understand science. Teachers said that the individual science project allowed them to clearly understand the scientific method for the first time. This experience made them feel more strongly the importance of students designing and conducting independent scientific inquiry. They learned that "scientists must be flexible, procedures can be changed, and that one real, but nevertheless useful, outcome of systematic inquiry is that data do not always support a proposed hypothesis" (McGee-Brown, 1995, *Case Study*, p. 39). Teachers thought they would be better able to convey these understandings to their students as a result of their own experiences.

Conclusions

We believe that future professional development projects for science teachers should be developed and team-taught by collaborative teams of scientists and science educators who understand both the process of scientific investigations and the appropriate pedagogical techniques for transferring this process to the classroom. We strongly believe that to teach inquiry-based science, teachers must first experience it. They must participate in programs in which they are immersed in a model of the type of scientific research that is appropriate in their classrooms. They must see themselves as scientists working collaboratively to answer questions about how the world works. They must at the same time be presented with ideas, activities, classroom management strategies, and assessment techniques appropriate to this type of instruction. In addition, long term support must be provided as teachers attempt to implement a program that for many is so radically different from what they have previously used.

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