Professional Development for Elementary Teachers: The Value of Modeling Inquiry

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Two professional development programs in which college science faculty modeled inquiry to facilitate content learning were evaluated to determine the impact on subsequent teaching and student learning.

Abstract

Elementary teachers rarely have expertise in science, including the nature of science content. This need is an issue to be addressed in professional development. Teacher educators have promoted the use of indirect methods, including inquiry teaching. The presenters evaluated professional development programs provided by two private liberal arts colleges in Virginia in which science faculty modeled inquiry teaching to facilitate teacher content learning. Data was collected and analyzed on the impact of this modeling on participants' subsequent teaching and student learning. A cohort of teachers in one of these programs was followed to see if the inquiry approach was implemented in their classrooms.

Introduction

Many teachers do not hold accurate perceptions of what constitutes scientific knowledge, scientific inquiry, or the nature of science (Lederman, Lederman, Khishfe, Druger, Gnoffo, and Tantoco, 2003). Because many teachers teach science by direct instruction, they may indirectly communicate to students through classroom activities that science is the information found in textbooks and scientific processes are simply verification activities found in lab manuals. As a result of inappropriate pedagogy, many adolescent students experience science as fragmented and incoherent. They are "showered with decontextualized dates, names, discoveries, and ideas that make little immediate sense to them." (Csikszentmihalyi, Rathunde, & Whalen, 1993, p. 118) One approach to address this situation has been to provide professional development activities for p-12 teachers focusing on the nature of science and the use of indirect methods, including inquiry teaching.

We are collaborating in an ongoing evaluation study of recent professional development programs designed for teachers by two private liberal arts colleges in Virginia. Both programs were concerned with teachers epistemological development, that is, a change in their relationship to knowledge, in this case, science. Both programs focused upon inquiry teaching and learning, and in both programs science faculty model inquiry-based science teaching to facilitate content learning by

teachers. Our interest is to describe and analyze assessment data on the impact of modeling by the science faculty on participants' subsequent classroom instruction. The findings to be presented are part of a continuing study of the results of modeling inquiry in teacher professional development, especially in terms of changes in teacher classroom instruction.

Inductivist teaching and the inquiry approach

Reform projects of the past two decades in p-12 science curriculum and instruction have focused on portraying the nature of science (NOS) more accurately to students, especially the preeminent feature of the nature of science, the process of inquiry (Bentley, Ebert, & Ebert, 2000). *Science as inquiry* is one of eight content standards in the National Science Education Standards (NSES). According to the NSES, "Science as inquiry is basic to science education and a controlling principle in the ultimate organization and selection of students' activities." (NRC, 1996, p. 105) And that, "Inquiry is a critical component of a science program at all grade levels and in every domain of science, and designers of curricula and programs must be sure that the approach to content, as well as the teaching and assessment strategies, reflect the acquisition of scientific understanding through inquiry." (p. 214) Thus, according to the NSES, all students should develop abilities necessary to do scientific inquiry, as well as develop an understanding about scientific inquiry.

Scientific inquiry is defined by the National Academy of Sciences (Committee on Development of an Addendum, 2000) and refers to the multiple ways scientists study nature and propose explanations for phenomena based on the evidence they derived. In the classroom, inquiry refers to the activities in which students develop understandings of concepts and of how scientists work. Further, inquiry is a teaching method in which students themselves conduct investigations.

In terms of pedagogy, inductivist approaches are frequently presented and demonstrated in p-12 teacher education courses and in professional development programs for practicing teachers. However, students in teacher licensure programs have diverse academic backgrounds in science, and for those seeking to become elementary teachers this background is often minimal. Typically pre-service elementary teachers take only a few tertiary-level courses in the natural sciences. These science courses are likely to be so lecture-textbook dominated and "overstuffed" with content that the nature of science and science as inquiry are minimally addressed and rarely modeled. Since the beliefs that teachers hold about the NOS and of science teaching and learning play an important role in their classroom decisions and practices (Bradford & Dana, 1996), participation in professional development programs in which the inquiry approach is not only advocated but modeled by science faculty may influence subsequent choices teachers make in providing classroom science activities for students.

The professional development programs we investigated were conducted at two small private liberal-arts institutions. The instructional focus was inquiry science teaching as modeled by science faculty. In demonstrating to teachers that they could meet state content standards by using an inquiry approach, these projects aimed to change the prevailing emphasis on direct instruction in teaching science. In this study, we are examining the impact of these programs on participants' subsequent choices of classroom activities and their perceptions of the results of using these activities in their classrooms. We ask: Did the modeling of inquiry-based science teaching by science faculty make any difference in the pedagogical practices participants implemented in their classrooms?

The Professional Development Projects

The projects we investigated promoted inquiry teaching in p-12 science education when liberal arts science faculty facilitated inquiry-based activities for teachers. In these projects, supported by the Dwight D. Eisenhower program through the State Council of Higher Education of Virginia, inquiry-based activities mean *open-ended* investigations rather than replications of experiments with predictable results.

We surveyed participants from three iterations of a program at one institution (1999-2000, 2000-2001, and 2001-2002) and of one program at the other (2002). In 2002, twenty-five grades 4-6 teachers participated in Hollins University's Active Learning in Elementary Science project. This program focused on content specified in the NSES and in the Virginia Standards of Learning (Board of Education, 1995) in life, physical, earth-space science, and NOS. Hollins science faculty modeled an inquiry approach. Participants also learned about active learning strategies (Harmin, 1998), integrated curriculum, differentiated instruction (Tomlinson, 1995), and community resources and technology. Ongoing resources and a communication network are available through a Website (http://www1.hollins.edu/classes/hesit/homepage.htm). Hollins University is an independent college for women located on a 475-acre campus in Roanoke, Virginia, offering a liberal arts program for undergraduates and licensure and master's degrees in education.

Sweet Briar College's inquiry-based science workshops began in 1999-2000 when science faculty implemented the first of multiple Eisenhower-funded projects. Participants had the chance to experience twenty chemistry modules that were linked to the Virginia Standards of Learning in grades 6-12. Following a summer institute, teachers were given laboratory equipment for their own classrooms and returned for follow-up meetings to continue their engagement. The first year, workshops were offered in chemistry, biology and physics to teachers in grades 4-8. In subsequent years the project expanded to include chemistry, biology, environmental science, and mathematics. Participants in the 2002-2003 project iteration are being surveyed at this time. Data from the 2003-2004 iteration includes

assessment of participants' implementation of inquiry teaching as demonstrated by a sample lesson. From this latest data was collected on the classroom implementation practices of these teachers. Sweet Briar College is an independent liberal arts college for women located on 3,300 acres twenty miles north of Lynchburg, Virginia that offers an MAT licensure program and the MEd in differentiated curriculum and instruction.

Method

The first data was taken using a questionnaire to survey teachers about their observations and perceptions following their participation in the professional development projects. The questionnaire (see appendix) asked about post-project teaching methods and any impact on student achievement and/or motivation that they believed resulted from students experiencing inquiry teaching.

Further, teachers who participated in the 2003-2004 Sweet Briar program agreed to give a presentation about a lesson they taught in their own classrooms using processes they learned during the summer workshop. They were offered a stipend if they presented their lesson, but they were not required to teach an inquiry lesson in order to receive the stipend. However, forty-two teachers (81%) elected to present. All of the teachers in this group had also taken other inquiry workshops offered through previous grant projects. Of the ten teachers (19%) who chose not to complete the requirements, four (40%) had had prior experience with inquiry in other workshops while the remaining 60% had had only the experience of the 2003-2004 workshop.

Forty-two teachers gave presentations to their peers and described the lesson and how it worked with their students. These presentations were videotaped for documentation and review. As the teachers talked, two faculty listened to their descriptions and scored them independently on an inquiry rubric created by the authors. The rubric used common characteristics of inquiry teaching based upon a definition of the inquiry method in the NSES. The intent of the rubric (appendix) is to quantify the level of involvement that teachers exhibited after they completed a workshop using the inquiry approach.

From these data we infer something of the impact of the inquiry-oriented professional development projects on participants and their students' science learning.

Results

Data from the questionnaire administered December 2002 to February 2003 are displayed in the graphs. Figure 1 a (the Hollins cohort) and 1 b (the Sweet Briar cohort) illustrate responses when participants were asked how often they used inquiry-based activities. Most respondents use inquiry activities once per week or less. Note, however, what one elementary teacher of 15 years said:

> I marked 'less than 1 per week' on #1. I felt it was hard using the given choices – I try to do something inquiry based with each unit we study – these usually take at least 2 class lessons to complete. I also like to do unrelated activities between units – many of these last more than one class session.

The results of the analysis of the 42 teacher presentations provided more insight into the impact of the professional development workshop. Category 1 of the rubric (see Appendix 3) was used to assess the level of student involvement in the lesson, ranging from teacher demonstration (1) to multiple approaches (4). The average score of 3.24 indicates that teachers were inclined to use methods where students were actively engaged in observation or experimentation.

Category 2 assessed the use of tools of inquiry, including mathematics in the inquiry process. The average score of 3.16 suggests that the teachers were approaching inquiry teaching with several tools but not using a rich variety.

Category 3 of the rubric focused on collaboration as an element of inquiry. The average score for this category was 3.01, suggesting that teachers were using some cooperative groups or teams but did not rely on collaboration exclusively when using the inquiry approach.

Category 4 addressed the level of student involvement in analysis and explanation in the inquiry process. The average was 3.00, described on the rubric as allowing students to "conduct some analysis; do some explaining, and/or make some links" to scientific knowledge. Teachers gave their students some freedom to explore but not to the level of open-ended investigation.

Category 5 assessed the level of communication that students experienced in the inquiry process – were students allowed to communicate their own processes of inquiry? The average score for this category was 3.09, suggesting that teachers gave students some opportunities to explain their procedures but did not allow them to explain all aspects of their investigations.

Category 6 addressed the methods of assessment that teachers employ while using inquiry-based instruction. The average score for this category was 2.84, suggesting that teachers have moved beyond reliance on textbook worksheets to using more than one method of assessment.

The final category described an instructional approach continuum with '1' as teacher-centered lecture or text-focused instruction and '5' as student-centered open or guided inquiry. The average score for this category was 3.48 suggesting that teachers are occasionally using inquiry-based instruction that may be structured in some cases, open/guided in others.

Discussion of results

Survey findings from the study at this point are limited by several factors. Although the Hollins and Sweet Briar participants were surveyed with the same instrument, the groups experienced different

inquiry-based programs. In addition, teachers surveyed from the Sweet Briar group were participants from programs spanning a three-year period, with the fourth year being surveyed now. The researchers make no attempt to control for differences in the programs, focusing instead on the findings from both programs that affect students. Because of the limitations of this study, we make no claims to generalizability. We do think, however, that these findings warrant attention because they describe trends in teacher perceptions of student achievement when inquiry-based science instruction is modeled and implemented in p-12 classrooms. The response sample is predominately K-6 teachers with some middle school teachers responding in the Sweet Briar group.

From Hollins, 9 out of 22 participants responded, a return rate of 41%. From Sweet Briar, 35 out of 126 responded to the survey, a return rate of 28%. In 2003, 80 teachers participated in an inquiry-based professional development program at Sweet Briar. Teachers were asked to volunteer to present a sample lesson that had been implemented in their classrooms. The lessons were presented to peers and Hollins faculty in 2004 and were rated using a rubric and analyzed for their application of inquiry as defined by the NSES and other documents (AAAS, 1993).

We find that most participants are using inquiry-based science activities about once a week and that participants have noted some gains in student achievement - interesting in light of the standards-driven environment dominating public education in Virginia. The categories of student achievement where teachers perceive the most gains are: teacher-made exams, hands-on activities, student problem-solving and recall of content. We found the last category surprising since inquiry-based instruction is usually linked with process rather than content learning. The participants' comments, however, indicated that teachers believed that students remembered the content better and could use the information to solve problems, especially on teacher-made tests. As one middle school teacher of 32 years reported:

> Our SOL scores have increased in science. I review students for tests and they know more answers and do better on test scores. Just this last week, gave the students a section of a chapter on work. The majority of the students could use and get the correct answers for problems on work and power.

She continued to note that her students "did not need prodding" or "needed very little help" in calculating problems and were adept at picking out important information in chapters.

An elementary teacher of 35 years commented that, "Students understand concepts better after doing inquiry-based activities. The concepts have more meaning to them. The students take ownership and feel they have discovered and made conclusions on their own." Another elementary teacher, this one with 15 years experience, noted, "I feel inquiry based teaching helps each student really understand the concepts, helps them build self-confidence, and helps them enjoy science!"

While these comments are reflective of the impact of inquiry-based teaching on student learning, our results indicate teachers clearly perceive positive effects on student motivation. For instance, in the Sweet Briar cohort 25 out of 35 responses to the question concerning the impact of inquiry on student motivation (#5) stated that their students were more receptive to learning. An elementary teacher with 4 years experience stated, "Students are eager to participate, anticipate coming to science class with pleasure, and have been motivated to extend and continue their learning outside the classroom." These results support findings that hands-on learning positively impacts students' motivation to learn.

Teachers also cited no negative effects on student achievement. When negative comments were offered, they were not directed to student outcomes. A few respondents made negative comments about the difficulty of implementing inquiry-based science with large numbers of students or they cited the lack of funds and equipment as a difficult problem to surmount. One elementary teacher of 26 years did report, "At times, students will remember doing something investigative but don't remember why or the total concept. They remember the foods, the water and sponges, the egg, but not plate movement in three ways or density concepts." While the teacher comments were directed to a specific activity on plate tectonics, her conclusion that inquiry-based teaching does not necessarily lead to conceptual clarity is a comment that we did not anticipate.

From the data for the presentations by teachers about their lessons we found that teachers use both structured and guided inquiry approaches. The level of student involvement in the lesson is a crucial variable. Teachers seem ambivalent about the amount of student control that they will allow or tolerate. They use inquiry but it is not clear how much time that they provide for students to collaborate or to discuss their work as part of the inquiry process. The average scores of 3.01 for collaboration and 3.00 for student analysis of findings suggests that teachers use cooperative groups and allow students time to explain their findings within a more structured or guided inquiry framework. The analysis explains why the continuum (category 7) shows an average score of 3.48, demonstrating that teachers are primarily using inquiry-based instruction at the structured/guided level.

Analysis of the lesson presentations offers some insight into the teachers' level of commitment to inquiry-based teaching following modeling and instruction in the use of inquiry. Although the NSES advocate inquiry as the instructional approach of choice in science education, teachers still believe that inquiry-based instruction is difficult in a standards-driven environment.

Discussion among the teachers following peer presentations provided additional data about the modeling of inquiry in professional development. Many believe that inquiry-based instruction is too time-consuming in terms of the demands on them to cover multiple subject area standards. Many do not recognize that inquiry can and should be used so to facilitate student understanding of concepts in

science. Many teachers need to work on time management. Many are not yet comfortable with taking the time to teach by inquiry, even though it may produce better understanding and perhaps better test results. Some teachers continue to confuse inquiry with hands-on activities. Some still see inquiry as suitable only for "extend" activities, and mainly or only for gifted children. We often heard that "slower" children need structure and "bright" children can learn independently (while both groups may initially need structure but the goal is to foster independent learning through a habit of mind, a process by which children investigate). While teachers are committed to hands-on instruction they may not see the difference between having students go through a clever activity versus completing an investigation in which the students themselves take charge of the process.

Overall, the professional development programs at Hollins University and Sweet Briar College produced similar results. Following inquiry modeling by science faculty and consideration of inquiry as a key feature of the NOS, teachers became committed to using an inquiry approach at least for some lessons. Those who used an inquiry approach saw real differences in student motivation and in a number of student behaviors. These results are consistent with what might be predicted from Social Learning Theory, where *imitation* is found to be a powerful strategy for learning (Bandura, & Walters, 1963; Bandura, 1977). They are also consistent with other studies that have found that in-service teachers who have had opportunities to experience inquiry as part of professional development workshops have credited the experience for changing their practices (Carnes, 1997).

We note that some respondents reported gains in standardized test scores and this finding merits more investigation, especially in an environment driven by test score results. Several studies have indeed found that student achievement improved after implementing inquiry-based methods, and these studies have found improvements to be consistent across socioeconomic levels and races (Kahle, Meece, & Scantlebury, 2000; Schneider, Kracjcik, Marx, & Solloway, 2002).

Conclusion and recommendations

We found evidence that teachers who agree to participate in inquiry-based workshops return for more experience with this process approach to teaching, suggesting that they recognize the value of inquiry and want to become more proficient in adapting it for their own classrooms. From the analysis of the 42 teacher presentations on their instruction, the average score of 3.48 suggests that teachers are committed to the use of inquiry in their classrooms. That all of these teachers returned for one or more inquiry workshops is indication that they are committed to the value of inquiry. Teacher disposition may be the key indicator of the priority that teachers place on the use of inquiry.

Many times we heard that time constraints and the standards-driven environment are barriers to using inquiry-based instruction. Direct instruction, with its emphasis on teacher-driven instruction,

continues to be the primary mode of instruction in science classrooms because teachers are not fully comfortable with student-directed investigation. This issue is trust-related because teachers have not always established a suitable classroom environment where teacher and students are co-investigators interested in finding answers to questions rather than struggling for control of the classroom environment. There is a need to address the management of the classroom environment so that teachers may employ inquiry approaches without jeopardizing student achievement or their own sense of purpose.

Finally, more insight into the relationship between modeling of inquiry teaching in professional development programs and classroom outcomes might be gained from structured interviews of a random sample of the teachers who participated in the programs. Also helpful could be teacher classroom behavior assessments to determine changes in teaching methods employed by the teachers after the project interventions.

Our results support continued efforts to implement teacher development programs where the participants experience inquiry teaching for themselves, along with supporting materials to assist them in conducting the activities with their own students. Results such as those achieved in these professional development projects may help to dispel the myth that students will not achieve in a content-driven environment or pass standardized tests unless direct instruction is the dominant pedagogy.

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Appendix 1

Eisenhower Program-Sponsored Project Participant Survey

Please answer the following questions by circling the response that best describes your experience. In some cases, you will be asked to write a response. Please feel free to use the back of the survey to complete your statement. Thank you!

1. How frequently have you used inquiry-based activities in your science teaching since your 2003-2004 Eisenhower experience?

(a) not at all
(b) less than once a week
(c) once a week
(d) more than once a week

2. How has inquiry-based teaching affected student achievement in your classroom?

(a) No observable differences have been noted.
(b) Some gains have been observed.
(c) Moderate gains have been observed.
(d) Large gains have been observed.

3. If you indicated in question 2 that gains in student achievement have been observed, which performance indicators have shown improvement? Check all that apply.

____ Performance on teacher-made exams
____ Student assignments, like homework
____ Student projects
____ Standardized tests results
____ Hands-on classroom activities
____ Student problem-solving in the classroom
____ Student recall of content
____ Other (please state)_____