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ABSTRACT

This paper defines the nature of purposeful science teaching, describing how two Virginia professional development programs for teachers utilized science faculty for instruction in inquiry-based science. Both projects involved summer institutes for teachers that modeled inquiry-based science teaching so that teachers could seriously implement the method in their classrooms. They distinguished between the use of hands-on and inquiry-based activities by focusing on the nature of science as open-ended investigation, rather than the replication of an experiment with predictable results. Surveys of participants in both programs examined the frequency of inquiry use in their classrooms and the influence that approach had on student achievement and motivation. Overall, teachers in both groups were using the inquiry approach less than once or week or at least once a week. There were some gains in student achievement, particularly with student problem solving, student participation in hands-on activities, teacher-made tests, and student recall of content. Teachers in both groups reported gains in student motivation due to the inquiry approach, even in the high-stakes testing environment. Respondents cited no negative effects on student achievement. Two appendixes present the survey and four figures. (Contains 16 references.) (SM)

Assessing the Impact of Inquiry-Based Science Teaching in Professional Development Activities, PK-12

A paper presented at the 2003 annual meeting of the
Association of Teacher Educators
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Despite widespread acceptance of inquiry-based science teaching among science educators, researchers report that most science instruction in PK-12 classrooms is teacher-centered and dominated by the use of whole group methods, such as lecture and textbook reading. Because textbook-based "hands-on" activities may not employ inquiry science, students seldom experience the process of inquiry for themselves. They think of science as a collection of textbook facts demonstrated by verification activities found in the experiments that they occasionally conduct (Grossen, Romance, and Vitale, 1994; Bentley, Ebert, and Ebert, 2000; Rescher, 2000).

The purpose of this paper is to define the nature of purposeful science teaching and to describe how two professional development programs for teachers utilized science faculty for instruction in inquiry-based science. Assessment results from both programs demonstrate the effect these programs had on teacher perceptions of student achievement.

Inquiry-based teaching is not a new phenomenon. As Robert Yager (1997), a prominent figure in science education wrote, "Inquiry was a major focus for the reform efforts of the 60's. ...During the two decades following Sputnik, two billion dollars were used in the United States to reform school science – almost always with an emphasis on 'inquiry.'" Jerome Bruner (1960) in *The Process of Education* describes inquiry as the process of discovery where students find solutions to problems through scientific investigation. Hilda Taba's (1971) inductive model allows students to organize and categorize data and hypothesize about the accuracy of their decisions. Despite widespread acceptance of inquiry teaching by science and social science educators since World War II, inquiry or inductive methods of teaching have never really become a viable choice for classroom teachers. Why is inquiry so infrequently used?

The nature of science involves a process of investigation, a process unique to every individual. While no two people may perceive the same phenomenon in the same way, they can verify their perceptions through formal investigation. Inquiry-based teaching allows teachers and students to investigate and hypothesize about the natural world and to use the data that they have accumulated to test these perceptions. In this sense, inquiry-based teaching involves teachers and students in investigating natural phenomena based upon their curiosity and interest. Inquiry-based teaching allows teachers and students to participate in the process of investigation, allowing their natural curiosity and interest to become a motivating factor in classroom instruction. Inquiry or inductive method is not just a replication of a lab experiment in a textbook. It is more closely associated with the constructivist perspective where investigations allow for student-generated hypotheses and solutions are not provided at the back of the book. (Bentley, Ebert, and Ebert, 2000). The dynamic nature of science is brought to life by inquiry-based classroom instruction. For science educators, it is the method of choice for classroom instruction.

Classroom teachers, taught with cookbook approaches to science, frequently replicate such patterns with their students. Teachers complain that inquiry activities take too much time from classroom instruction or that students become unruly when allowed to move around the room. Science as an investigation of natural phenomena becomes the process of replicating experiments largely devoid of meaning to students who have no relationship to the event. As Csikszentmihalyi, Rathunde, & Whalen (1993) found, "Such students feel they are showered with decontextualized dates, names, discoveries, and ideas that make little immediate sense to them." This study also reports that science teachers are more authoritarian than their colleagues in other disciplines.

While these issues of cook-book labs, textbook inadequacies, and teaching-as-telling are fundamental problems in science teacher preparation, another more powerful threat has developed in the last decade: the use of high stakes standardized tests. As Amrein and Berliner (2003), note, citing Sheldon & Biddle (1998):

> ... high-stakes tests cause teachers to take greater control of the learning experiences of their students, denying their students opportunities to direct their own learning. When the stakes get high, teachers no longer encourage students to explore the concepts and subjects that interest them. Attaching stakes to tests apparently obstructs students' path to becoming lifelong, self-directed learners and alienates students from their own learning experiences in school. (pp. 32-33)

As these same researchers report, there are currently eighteen states that use high-stakes testing and the results of their study show that there are many other harmful side effects, including a decrease in student motivation and higher student retention in grade and higher dropout rates. (p. 34) The No Child Left Behind legislation will only exacerbate the situation by mandating yearly testing for grades 3 through 8.

The difficulties that science teacher educators and science teachers must face are very complex. All of the major national curriculum reform projects of the last decade, including the National Research Council's National Science Education Standards (NRC, 1996) and the American Association for the Advancement of Science's Project 2061 (AAAS, 1993) extol the importance of the inquiry-approach. Little or no modeling of the approach in teacher preparation programs, coupled with textbook inadequacies, lack of systemic support in the school, and the demands of standards-driven instruction, have combined to undermine the use of inquiry in science and social science classrooms.

While these odds may seem insurmountable, two professional development programs in a high-stakes testing state focused on inquiry as a way to teach content standards. The goals of these programs were not simply driven by the use of inquiry. They intentionally sought to provide hands-on science activities for teachers, relating them to state standards and to the nature of science. In demonstrating to teachers that they could meet the standards by using inquiry, these projects hope to break the grip that direct instruction maintains in science classrooms. The two professional development programs were designed for Virginia teachers by two private liberal arts colleges and funded by the Dwight D. Eisenhower Professional Development Program of the U. S. Department of Education. In both programs, science faculty in biology, chemistry, physics, and environmental science taught the concepts of their disciplines to elementary, middle, and secondary teachers who applied from school districts in their surrounding areas.

It has been found that the beliefs that teachers hold about the nature of science, as well as science and science teaching and learning, influence their classroom decisions and practices (Bradford & Dana, 1996). Professional development programs for teachers in which science faculty model the inquiry approach and provide teachers with an abundance of resources and activities, may influence teachers' choices of instructional activities for their students. Science faculty related the activities to the Virginia Standards of Learning, demonstrating that inquiry teaching could meet content standards if the teachers used activities such as those that had been modeled for them.

Description of the Projects

Two professional development projects in different geographic areas of Virginia developed summer institutes for teachers funded by grants through the Eisenhower Professional

Development Project. Liberal arts and sciences faculty modeled inquiry-based activities and observed teachers conducting their own investigations. Program evaluators for both programs surveyed these participants to see if they reported any changes in their students' achievement and motivation in science (see Appendix for survey instrument). The Sweet Briar College Professional Development Project had completed four iterations of its program while Hollins University had recently completed its first program. Survey data provide an opportunity to assess the effectiveness of the programs in modifying teacher-participant instructional patterns and in their perceptions of how students performed on a variety of assessments.

The Sweet Briar College Professional Development Project

Sweet Briar College is an independent liberal arts college for women located on 3,300 acres twenty miles north of Lynchburg, Virginia. Sweet Briar offers a liberal arts curriculum for undergraduates and licensure for elementary teachers, PK-6 and secondary teachers, 6-12. The first professional development project began in the summer of 1999 when college science faculty won the first of four Eisenhower grants to teach inquiry-based science activities for teachers in central Virginia. During the first summer workshop, twenty chemistry modules were modeled for teachers in grades 6-12. In the summer of 2000, the Eisenhower workshops offered twenty-five hands-on activities in chemistry, biology, and physics to teachers in grades 4-8. In the summer of 2001, the workshop offered teachers in K-8 a broad range of activities in chemistry, biology, environmental science, and mathematics. In the following summer of 2002, elementary teachers in K- 6 were invited to explore concepts in the same sciences, but new inquiry activities were modeled and practiced by the participants. In each academic year following the workshops, teachers returned to the College for one-day "academies" where they discussed inquiry in their own classrooms and investigated more activities for classroom implementation. Throughout each Eisenhower grant, teachers received additional supplies for use in conducting inquiry-based activities with their students.

The Hollins University Professional Development Project

Hollins University is an independent liberal arts college for women located on a 475-acre campus in Roanoke, Virginia, a metropolitan area of 230,000. Hollins offers a liberal arts program for undergraduates and licensure through master's degree in education. The Hollins Active Learning in Elementary Science project held a two-week intensive summer session in June 2002 and a final all-day session in mid-October. Twenty-two teachers in grades 4-6 participated in the summer institute where content specified in the Virginia Standards of Learning (Virginia Board of Education, 1995) and in the National Science Education Standards (NRC, 1996) was presented. Hollins science faculty and Virginia Museum of Natural History scientist/curators conducted hands-on, inquiry sessions addressing major concepts in the life, physical, and earth-space sciences. The program also focused on active learning strategies (Harmin, 1998), integrated curriculum, and differentiated instruction (Tomlinson, 1995). The project director and contributing scientists also addressed the nature of science as grades 4-6 curriculum content. Community resources and technology applications for the science classroom were also included in the program. A communications and institute web site (http://www.1.hollins.edu/classes/hesit/homepage.htm) was created to provide ongoing resources for participants and other teachers.

Method

Every participant in both professional development programs received a survey asking them a series of questions about the frequency of inquiry use in their classrooms and what influence the approach had on student achievement and motivation (Sweet Briar College, N = 127;

Hollins University, N = 22). The survey did not require teachers to provide raw data to support their claims. The survey reports teacher perceptions of changes in both motivation and student achievement (see Appendix).

Results

The survey data are displayed in bar graphs in the Appendix to this paper. Figures 1 (a) and (b) ask the participants how often they use inquiry-based activities in their classrooms. Respondents in both groups use inquiry activities once per week or less. Pre-workshop surveys conducted by Sweet Briar College science faculty indicated that the teachers were using "hands-on" science activities at least once per week prior to the workshop. There was no certainty, however, that these activities were inquiry-based, i.e., open-ended investigations. One respondent did comment, however, that she felt this question was difficult to answer. She writes:

> 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.

Figures 2 (a) and (b) display teachers' responses concerning perceived student achievement gains following the use of inquiry-based activities. Respondents in both cohorts recorded "some gains" in student achievement.

Figures 3 (a) and (b) asks teachers about the types of activities where they observed improvement in student achievement. Most respondents in the Hollins cohort indicated that students' problem-solving, participation in hands-on activities, and performance on teacher-made tests improved as a result of inquiry-based activities. The Sweet Briar respondents also favored those responses but chose "recall of content" as their second improvement in student achievement.

Figures 4 (a) and (b) asks teachers to respond to the effects of inquiry-based activities on student motivation. Most respondents reported that their students were more receptive to learning as a result of inquiry-based activities in their classrooms.

Discussion of Results

Survey findings from this study describe trends in teacher perceptions in student achievement following the use of the inquiry approach in their classrooms. Problems such as cookbook lab experiments, fact-driven textbooks, teaching-as-telling, and high-stakes testing have created fundamental problems for the implementation of inquiry. The purpose of the Sweet Briar College and Hollins University professional development programs was to model inquiry-based science teaching so that teachers might be willing to seriously implement the method in their own classrooms. Both projects distinguish between the use of "hands-on" activities and inquiry-based activities by focusing on the nature of science as open-ended investigation rather than the replication of an experiment with predictable results. Since Virginia is a high-stakes testing stake, the programs also sought to help teachers find ways to teach content standards without overtly directing the learning experiences of their students.

Analyses of the bar graphs indicate that teachers in both groups are using the inquiry approach less than once a week or at least once a week. They have also noted some gains in student achievement, particularly with student problem-solving, student participation in hands-on activities, teacher-made tests, and student recall of content. Respondents in the Sweet Briar cohort were more likely to report that their students could remember 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 (Standards of Learning) scores have increased in science. I review students for tests and they know more answers and do better on test scores. Just last week, I 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 of 15 years noted, "I feel inquiry-based teaching helps each student really understand the concepts, helps them build self-confidence and helps them enjoy science." It is important to note that these teacher comments also reflect another finding from this survey, the positive effect of inquiry-based teaching on student motivation.

Student motivation is perhaps one of the most vexing problems that teachers face in a standards-driven environment. Students are retained and drop out more frequently in this context (Amrein & Berliner, pp.32-33). Teachers in both cohorts, however, report gains in student motivation because of the inquiry approach, even in a high-stakes testing environment where the pressure to pass a standardized test can be very intense. For instance, in the Sweet Briar cohort, 26 out of 36 teachers stated that their students were more receptive to learning when they used inquiry-based teaching in their classrooms. An elementary teacher of 4 years writes, "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."

Teachers were also questioned about their perceptions of the negative effects of inquiry-based science teaching. The respondents cited no observed negative effects on student achievement. Some respondents commented about the difficulty of implementing inquiry-based science with large numbers of students or they cited the lack of funds and equipment. One elementary teacher of 26 years did report, however, that

> 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.

The teacher's comments were directed to a specific activity on plate tectonics but her conclusion that inquiry-based activities lead to conceptual confusion was worthy of note.

In summary, the effect of inquiry-based modeling on student achievement in science as reported by two groups of teachers who have been taught by science faculty in teacher professional developments programs are remarkably similar. Teachers found gains in several observable student behaviors and especially in student motivation. These results support continued efforts to implement teacher development programs where the participants experience modeling and practice with inquiry-based activities, relate inquiry teaching to the nature of science, and use supporting materials to assist them in conducting the activities with their own students.

Teachers also reported some gains in standardized test scores, dispelling the notion that students will not achieve in a content-driven environment or pass standardized tests unless direct instruction is implemented on a regular basis. These survey results show that teachers who implement inquiry-based science activities once a week or less have seen observable gains in student achievement.

Limitations

Survey findings from this study are limited by several factors. Both cohorts of teachers participated in professional development programs sponsored by science faculty who modeled inquiry science for their participants but they did not receive the same program in each instance. The researchers made no attempt to control for differences in the programs in the survey. The same survey was administered to both cohorts. The researchers make no claim that these results are generalizable to other populations, but note that these results add to the body of literature about the effects of inquiry-based science teaching, including effects on student achievement and motivation to learn.

Conclusions and Recommendations

Future studies of teacher cohorts from these liberal arts colleges might include structured interviews of random samples of teachers in both groups and teacher classroom behavior assessments to determine changes in teaching methods following the professional development activities.

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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 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)____________

Briefly explain your choices, citing relevant evidence that you have found to support your choices: ____
____
____

4. If you observed negative effects of inquiry-based teaching on student achievement, which performance indicators would you choose from the list? Check all that apply.

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

Briefly explain your choices, citing relevant evidence that you have found to support your choices: ____

____

____

____

5. How has inquiry-based teaching affected student motivation in your classroom?
   (a) No observable differences have been noted.
   (b) Students are less receptive/responsive to learning.
   (c) Students are more receptive/responsive to learning.

Briefly explain your choice, citing relevant evidence to support your observations.

____

____

____

6. Summarize the effects of inquiry-based teaching on student achievement in your classroom. Please take this opportunity to tell us about any effects that were not listed in the survey either positively or negatively.

____

____

____

7. We would like to ask the following questions for demographic purposes:

(a) How long have you been a teacher? ________________

(b) Are you an elementary, middle, or secondary teacher? ________________

(c) In the past five (5) years, have you participated in any other professional development activities – courses or workshops – specifically focused upon inquiry teaching? ________

If yes, can you please identify such activities? ________________________

____

____

____

Additional comments:

APPENDIX 2

<u>FIGURE 1</u>

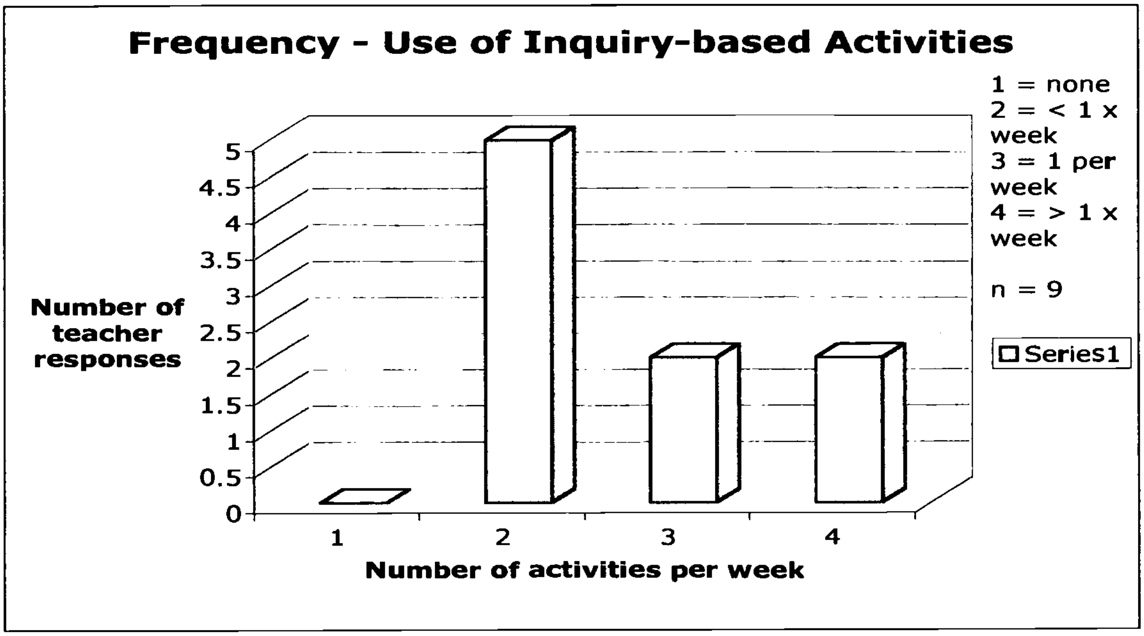

Figure 1 (a) Responses of Hollins project participants

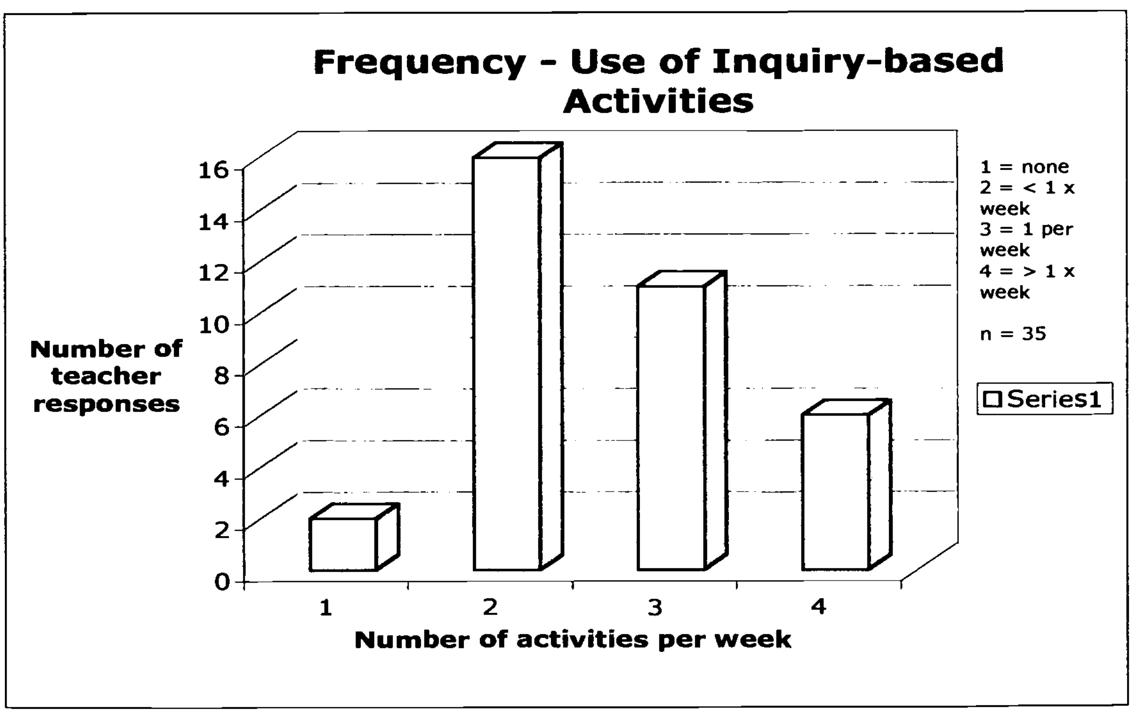

Figure 1 (b) Responses of Sweet Briar project participants. One survey had no response to this item.

FIGURE 2

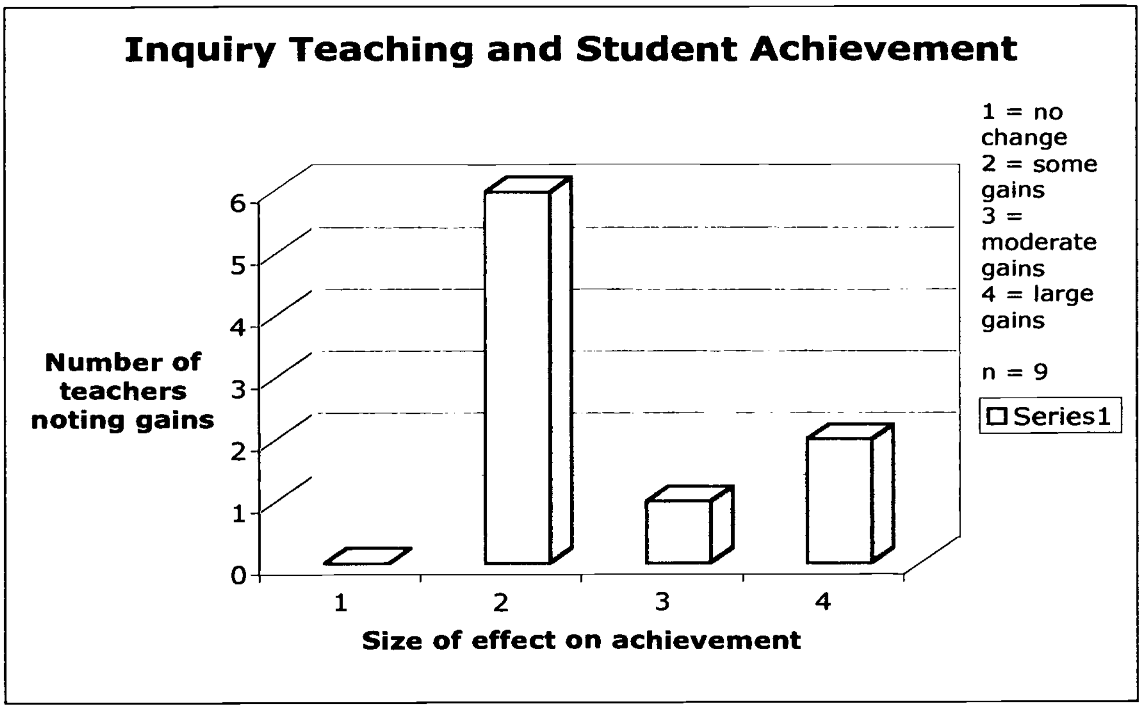

Figure 2 (a) Responses of Hollins project participants.

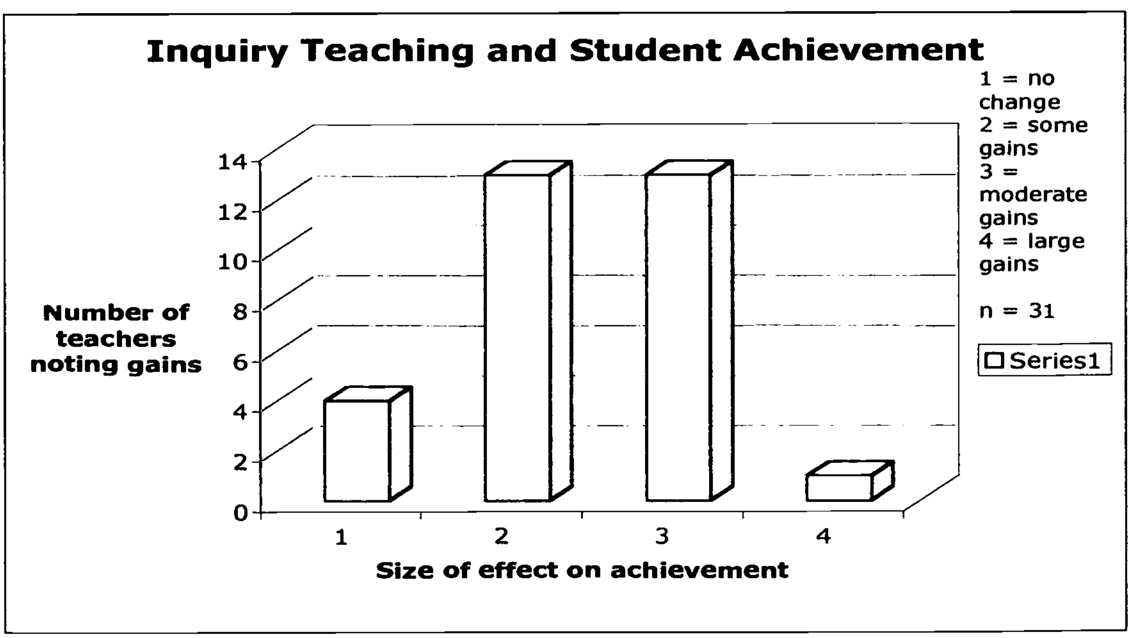

Figure 2 (b) Responses of Sweet Briar project participants. Five surveys had no response to this item.

FIGURE 3

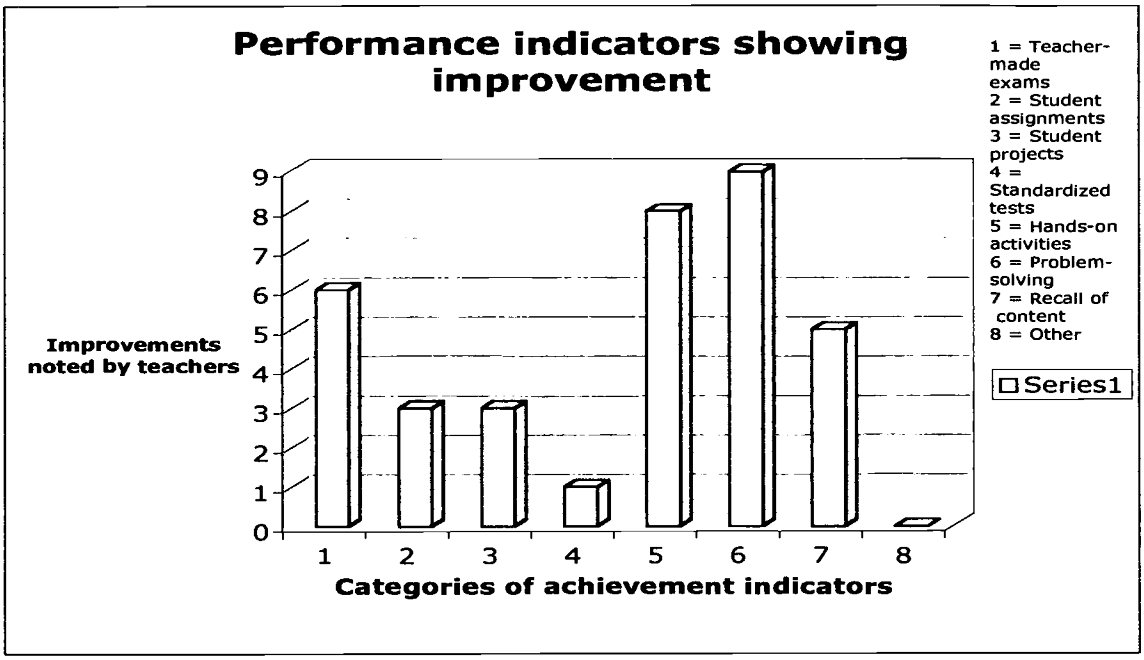

Figure 3 (a) Responses of Hollins project participants.

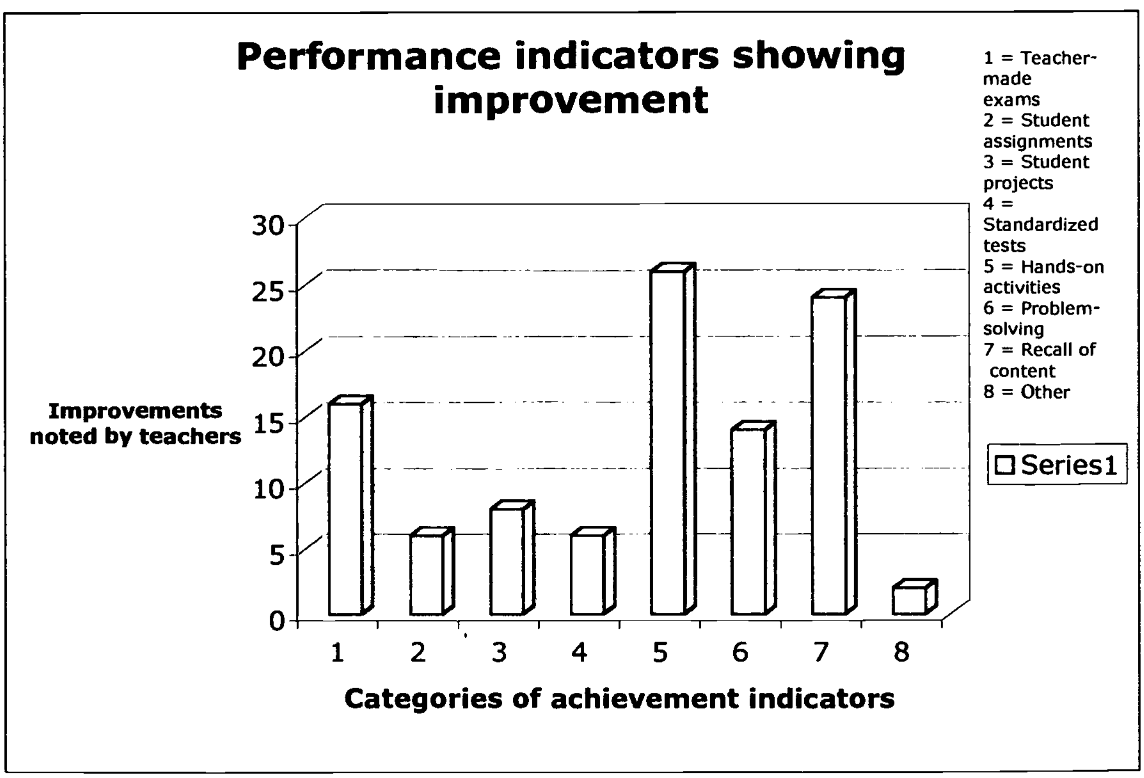

Figure 3 (b) Responses of Sweet Briar project participants.

FIGURE 4

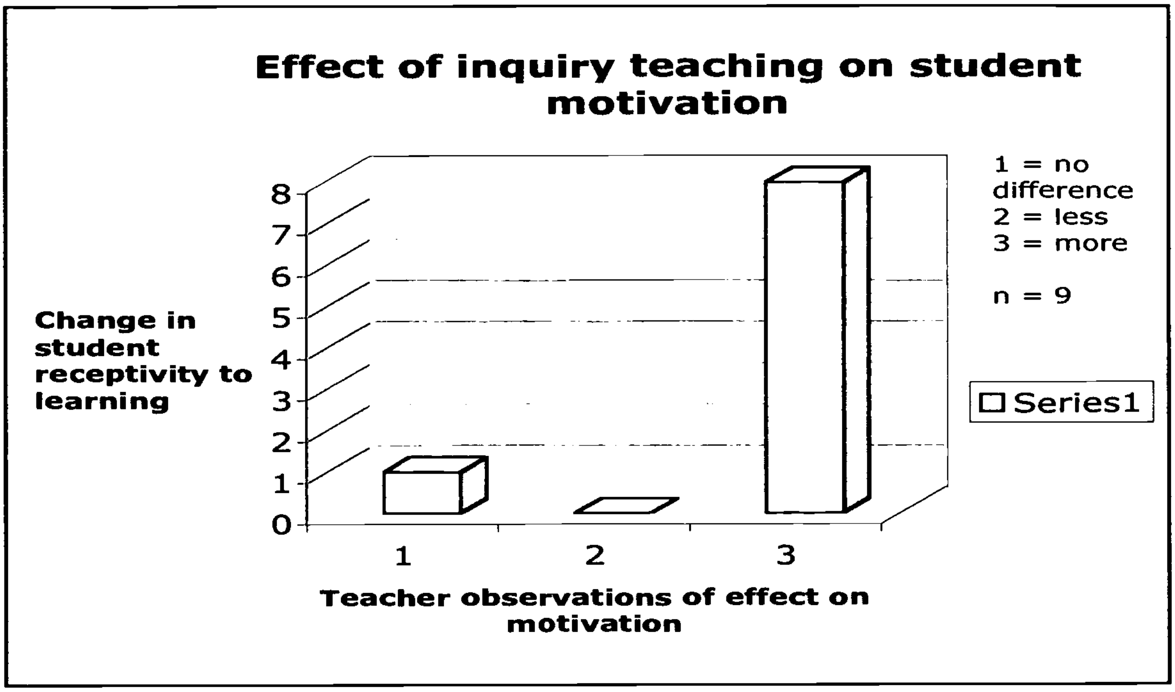

Figure 4 (a) Responses of Hollins project participants.

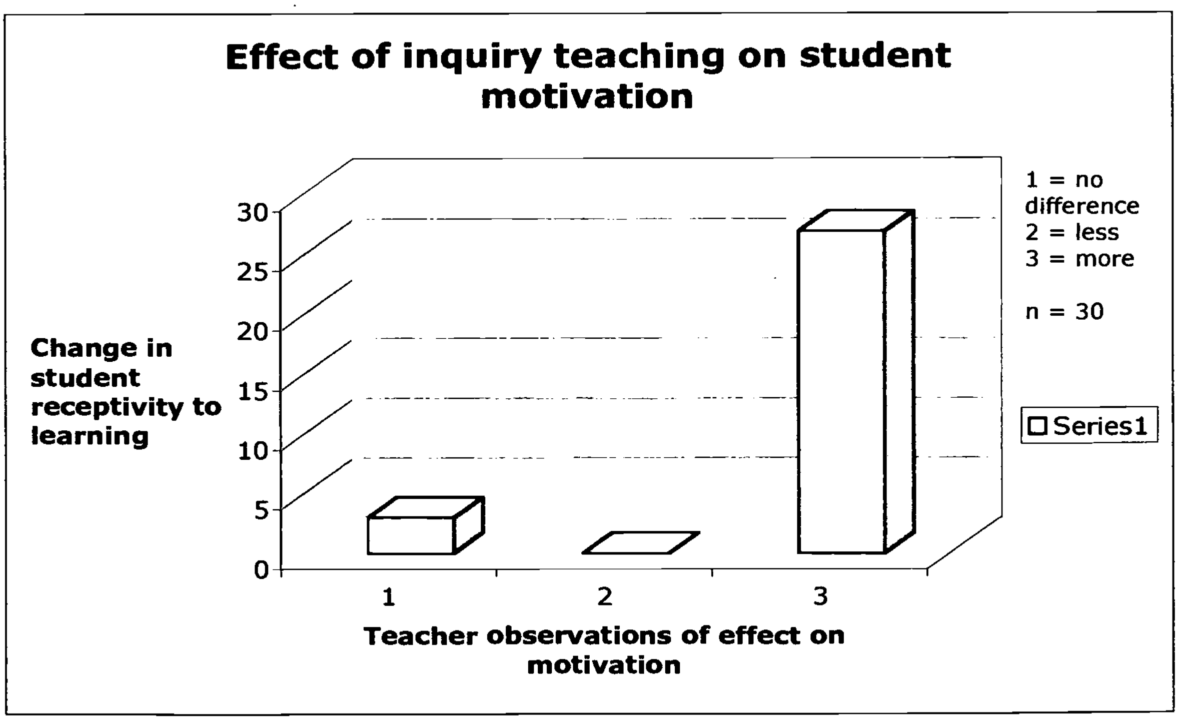

Figure 4 (b) Responses of Sweet Briar project participants. Six surveys had no response to this item.

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