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Saint Mary's College Teacher Science Institute: Converting Teachers to Using Guided Inquiry for Science Curricula

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Abstract

In 1998 Saint Mary's College received a grant from Lilly Endowment, Inc. to create a program to improve the quality of science education in the local public and private schools. As part of applying that grant we created one-week summer workshops for elementary and middle school teachers (K–8) based on guided inquiry methods of education. Each summer from 1999 to 2002 we have taught sixteen teachers in two week-long Teacher Science Institutes (TSI). This paper describes one part of the content and processes used in our workshops. Primarily it describes the teachers' enthusiastic shift to a constructivist, student-centered, guided inquiry pedagogy for science in their classrooms.

Introduction

Our Teacher Science Institute (TSI) is one component of a three-component project undertaken by Saint Mary's College funded by a Lilly Endowment, Inc. grant. The CoSTEP (College, Student, Teacher, Parents) Project includes Science Power Laboratories for students in grades 7-12 in home school or from disadvantaged schools. The second component is the Eureka Science Academy taught by Saint Mary's College education faculty as a summer camp for students in grades 4-6. Parents are part of both of these components. The TSI's are one-week summer workshops taught by our science faculty for teachers in grades K-8 in the local public and private schools. The teachers receive two or three tuition-free graduate credits and $300 of science education materials of their own choosing for use in their classrooms. A report containing a more complete description and outcomes for the entire project is in development. This report focuses on the TSI in the CoSTEP Project.

TSI Design and Assessment Methods

The science content and pedagogical processes in our TSI workshop are predicated on our interest in creating an environment that simulates the classroom environment we envision all teachers using for teaching their science curricula. Research in the field of science teacher education and our own experience support the claim that teachers will often teach they way they were taught *(McDermott 2000)*. To overcome this tendency, we teach our teachers using the methods we maintain to be the most effective for their students, guided inquiry investigations. We also think that they cannot fully understand or teach effectively using guided inquiry methods without experiencing them firsthand. They need to understand the intellectual and emotional transformation that using a student-centered, constructivist approach to science education will bring into their classroom. The following description of the workshop and its outcomes will clarify the effects of this type of instruction.

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The basis for our workshop design is embodied in current writings on best practices in teaching science *(Zemelman, Daniels, and Hyde 1998; McDermott 2000; Driver and Oldham 1986)*. Recommendations for teaching science include increasing classroom hands-on activities that focus on underlying concepts for developing the student's scientific understanding of natural phenamena. These include increased opportunities for observation and data collection, questioning, critical thinking, and application of problem-solving skills. We also subscribe to the constructivist view of learning as the most effective method for confronting and refuting misconceptions in order to understand and explain natural phenomena scientifically. Recommendations of best practices also include the use of collaborative small-group work, including training in working in groups to ensure that the learning is efficient and effective for all group members. We hold these same convictions and employ these methods in our workshops to achieve our goals.

Our workshop uses hands-on, inquiry-based team activities and focuses on the investigations of physical science phenomena. However, the applications of guided inquiry methods are easily adapted to the biological and earth science curricula.

We titled our workshop "Science as Creative Play" for two reasons. First, when one observes children at play it is easy to see that they create models and take risks. These are both important cornerstones of doing science. Second, we wished to remove the view that doing science is hard work, and that learning science is hard work not fun. There are three concurrent themes in our workshop. (1) The teachers experience guided inquiry methods to learn the content in our course. (2) They explore materials and lesson plans that are appropriate for their own grade level science curricula. (3) They engage in discussions on a broad range of topics that are intended to overcome real and perceived barriers associated with using student-centered, guided inquiry methods. While all three components are necessary for the overall goal of supporting systemic change, only the first is presented here.

Our primary objective is to move the teachers into using guided inquiry in their classrooms. This is accomplished largely by demonstrating the effectiveness of the methodology by providing them with the experience of learning science content themselves thorough guided inquiry instruction. A secondary objective is to make it fun but challenging in order to keep the teachers interested and engaged throughout the week. We monitor the teachers' attitudes about the workshop and about guided inquiry methods by reading the reflections they write at the end of each day. Assessment of the teachers' gain in content knowledge is achieved using pre- and posttests on the inquiry activities. For our long-term assessment we employ an outside evaluator for the CoSTEP Project.

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Using a Constructivist Curriculum

The pedagogical format of our workshop is based on the constructive theories of learning or the "construction of scientific knowledge" that directs the students to "try it and see if it works" in order to develop the scientific theory behind the phenomena *(Carey et. al. 1989). We use research-based guided inquiry curricula (NSRC 1998; EDC 1994; McDermott et al. 1996)* materials for the hands-on activities. These are student-centered learning materials and we serve only as facilitators to the teachers' understanding and progress through the materials. We want them to leave the workshop with a view of science as based on a knowledge about the world through observation and experimentation.

We initially describe this approach to our teachers using the following three points that constitute what we call "The Constructivist View of Science."

- Learning happens because of what you do.
- Models are ways that you think about the world.
- Everyone instinctively builds models, so everyone does science.

Another framing perspective for the activities in our workshop is presented to the teachers in the following three guiding principles of what we call "A Scientist's Perspective:"

- Being wrong is an opportunity to learn.
- Being right feels good but doesn't get you any new information.
- When you are doing something you have never done before why would you expect to be right even half the time?

By beginning their instruction within these framing guidelines we effectively set the stage for the intellectual and emotional encounters they will have with the guided inquiry materials we have chosen for the workshop. We assume teachers are creative and skilled in helping children, so we expect them to translate what we teach them into what will work in their classrooms. We know that guided inquiry methods are appropriate for all grade levels K–12 from our follow-up surveys. Though the style of the questions and activities might change, the process is the same for science education at all grade levels. This message is continually and consistently reinforced in every activity in our workshop.

Guided Inquiry Content and Process Materials and Methods

All of the activities and all of the discussions we have included in this workshop are important for achieving our major goal of systemic changes in science education. The most critical type of activity, a fundamental element of the design in the workshop, is embodied in the guided inquiry investigations related to theories about electricity. Specifically, teachers learn how batteries run motors and light bulbs in what we call M & B and B & B activities in eleven hours over five work sessions. It is this experience in guided inquiry learning that develops the teachers' content knowledge and gives them a sense of the power of learning through guided inquiry. They demonstrate to themselves that even teachers learn best by experience, constructing the models of science.

We begin with one open inquiry activity using motors and batteries. The final four sessions on electricity use the chapter "Bulbs and Batteries" from the text *Physics by Inquiry* by Lillian McDermott, Peter S. Schaffer, Mark Rosenquist, and the Physics Education Group of Department of Physics, University of Washington. This text is based on over twenty-five years of research in student learning for pre-service and in-service elementary school teachers. We chose this content because it is in the curriculum at many grade levels and it is not well understood by most teachers. In addition, many teachers have deeply held misconceptions about batteries and current that can be effectively confronted through using these research-based, guided inquiry materials. This topic compels them to learn difficult concepts and simultaneously lets them experience "being wrong as an opportunity to learn." We also are able to observe their change of view of their own learning process through these activities on electricity. Once this is achieved the teachers are readily convinced that their students will benefit from the same approach to learning science. We think that it also is imperative that they understand the emotional experience their own students will have when they teach using these methods.

"Being right feels good but doesn't get you any new information."

Building Teams That Work: The format of the M & B and B & B activities is student centered and team oriented. We pair teachers in teams using specific criteria that we consider important for working effectively on the electricity materials. For the M & B and B & B activities the members of each pair have three or more years' difference in grade level and a significant difference in teaching experience. The importance of applying these criteria has been reinforced throughout the four years of the eight workshops. Teams formed through non-optimal pairings have more often progressed slowly through the electricity materials and have required the most help from the facilitators to become successful.

The Rules in the Guided Inquiry Classroom: In order to facilitate the construction of knowledge, the process in the classroom is very structured. The basic learning cycle can be described as predict, observe, compare, and assess. The teachers are told to read the instructions and then discuss with their partner a prediction for any activity. They then write the prediction in their individual journals or notebook's. After completing the activity they write what they observed, stating whether it agreed with their predication. Through years of observing in our own classrooms we know that students will often rethink their predictions and restate them as if they had predicted correctly when they did not. To prevent this from occurring, it is imperative that they write down their predictions and review them after the experiment has been completed. Using this process o reviewing the incorrect predictions, the teachers identify and correct their own misconceptions. This is one of the foundations for arguing that these kinds of activities are effective at correcting misconceptions when prediction does not fit observed behavior.

Beginning the Constructivist Experience: To begin the guided inquiry work, we use a very simple open inquiry activity that can be successfully completed because we believe that the learners need to be successful in this first encounter with these methods for the initial motivation. The teachers are given a small motor with two wires attached and an AAA battery, and are told to make the motor run. Most pairs accomplish this feat in a few seconds to a few minutes. They understand the general function of batteries and that the wires need to be attached one at each end of the battery. Then we begin a dialog with them. How do you know it is running? Is there more than one way to tell if it is running. The answers seem obvious to them and are very simple. "I hear it running." "It buzzes." "I can feel it vibrating". Some teachers notice that a small shaft is turning and will touch it. Then we ask them if they can describe which way the motor is running? This generally results in most of them attaching something to the shaft to get a better view of the event. In this way we move them covertly from open inquiry instructions to guided inquiry instructions. Next they are given some written instructions to follow to accomplish more complex investigations with two motors and one battery. All of them are very successful at completing a large amount of the activity before time ends. Other easily accomplished experiments could produce the same successful outcomes.

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In the second electricity session each team of teachers began working with one set of instructions using the McDermott bulbs and batteries materials. We found that the best way to build a team is to be sure that the team must share information. Following the guided inquiry format in the McDermott materials, the teachers work their way through the text predicting the "behavior" of batteries and bulbs and discussing and writing down their predictions. They do the experiments, write the results, discuss and analyze the outcomes, and finally write the analysis before moving on to the next developmental piece of constructing knowledge about the scientific basis of how batteries and bulbs behave. We serve as facilitators, interacting only as they ask questions, often questioning in return. The McDermott materials are designed to support this kind of classroom environment. We never tell them whether their results and their analysis of them are "correct." This places them completely in the intellectual and emotional position of being students in a guided inquiry classroom. We have been profoundly surprised at the effectiveness of this method in developing their understanding the effectiveness and value of constructivist learning using guided inquiry methods.

The Moment of Conversion: We can predict approximately when the conversion will occur and how it will manifest itself to us and potentially to the entire class. It is best described beginning with a brief description of the bulbs and batteries materials and ending with an anecdote. We have consistently observed the following general behavior of the teachers in all eight workshops when they are working on the B & B material. At first most of them are completely frustrated. The source of their frustration is twofold. Most of the teachers are admittedly ignorant or have well-documented common misconceptions of the scientific theories concerning electricity and batteries. Also, as all good students do, they want reinforcement of the knowledge that they do possess. So when they begin the material and are confounded by not knowing anything about how to "light a small light bulb using a bulb, one wire, and battery," they cannot proceed, for long periods of time, through even the first paragraph of a ten page set of instructions and experiments. More frustrating to them is that we will not give them even a hint of what to do. We simply tell them to "try some things and see what happens." It has taken some teams as long as thirty minutes to make the light bulb light. Next they read that there should be four different configurations that will make it light, and they need to find them all. This same slow progress often continues through the first entire session of working with these materials and, for some, into the second day on the McDermott materials.

Many of the teachers are completely convinced of the accuracy of their own misconceptions about how a battery works and know nothing about how a light bulb is constructed. They continue to be frustrated when their experimental predictions are wrong. When moving to the more challenging material it becomes even more apparent that they are bound to their own ideas and they are continually confronting their misconceptions when their own observations do not support their theories. They will continue to try to prove that what they believe to be true is true even in the face of observations to the contrary until finally they must change their view in order to explain their observations.

"Even those who teach electricity discover that they possess some major misconceptions about electricity and batteries when the circuits get very complex."

The intellectual and emotional aspects of this method are illustrated in the anecdote of one teacher who became so frustrated at what she was observing that she stood up and shouted for everyone to hear, "Batteries can't do that!"—referring to the counter-intuitive observation that the battery current is not always the same, but differs in different circuits. But of course batteries can and do just that. Once she realized what she was saying, it became fundamentally clear to her that she was wrong. There is a moment of conversion similar to this, though not always as dramatic, experienced by almost every teacher in our institutes somewhere in the process of working with this material. Even those who teach electricity discover that they possess some major misconceptions about electricity and batteries when the circuits get very complex. Some teachers admit that they have been teaching it incorrectly to their own students, one even admitted to correcting more than one of her students when they had explained the behavior of batteries correctly. We know how profound the experience is for them because this is consistently stated in the reflections on the second or third day in the workshop. Many teachers' reflective comments show that they experience it as a moment of epiphany. This method of instruction is profoundly effective because the only explanation they find is to change their theories about batteries.

At or near this same moment, they realize that they have the ability to understand without our confirmation and they become "true believers" in this student-centered approach. After the first day or two of working with these materials, their own confidence rises and they begin to understand the value of guided inquiry to themselves. From there it is a short path to thinking about how they can apply it in their own classrooms with their own students. This is helped by the grade level activities we include in the workshop and by the $300 of science materials they purchase at the end of the week. Space limitations preclude a description of the grade level activities here.

> *"[When teachers] realize that they have the ability to understand without our confirmation . . . they become "true believers" in this student-centered approach."*

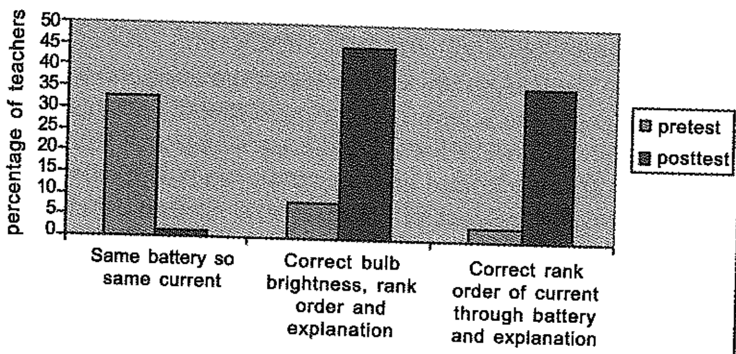
Guided Inquiry and Outcome Assessment

We also are reasonably satisfied with the teachers' increased understanding of the scientific theories related to batteries, bulbs, and electricity. We needed to show the teachers that this process of teaching is effective toward gaining content knowledge that can be readily assessed. The McDermott materials contain excellent imbedded self-assessments as well as opportunities for the facilitators to assess the students' progress through the material. In addition, each morning before beginning the B & B activity we give an assessment based on the content from the day before. We verify that every team has covered enough material to correctly answer the text question. During the course of the week the in-class assessments generally yield about 95 to 98 percent correct answers. In one follow-up meeting with twenty-one teachers we determined that most of them had retained much of what they had learned in the workshop. All but one of the teachers was able to correctly complete a drawing of a working circuit from two months to more than one year after completing the workshop.

All of the teams get through a significant amount of the guided inquiry text materials. A few, though not many, teams complete the entire chapter on bulbs and batteries by the end of the last scheduled period. We also give a pretest/posttest that is more challenging than the in-class assessments. The teachers are asked to rank order the brightness of bulbs in three circuits and to rank order the current through the battery in the circuits. The outcome for this assessment is shown in Figure 1.

At the beginning of the workshop most of the teachers do not know anything about reading and understanding a circuit diagram, much less understand anything about the behavior of batteries and current in a circuit. Many of those who teach the subject hold one major misconception, that batteries always produce the same current. When they complete the workshop all of them can read a circuit diagram and are genuinely pleased to be able to understand the questions being asked on the posttest. The first column in Figure 1 illustrates the level improvement in the teachers' knowledge of the current that batteries produce. The second and third columns demonstrate a significant improvement in the teachers' understanding of current through parallel and series circuits.

Figure 1: Bulbs and Batteries Assessment



Our success at achieving systemic change in the local schools has been mixed. At the relatively autonomous private schools many of our teachers have been able to create the science education environment we envision, including largely hands-on guided inquiry methods in most of their science curriculum. In the first two academic years following our workshops we were able to confirm an increase in the amount of time devoted to science and in the use of guided inquiry instructions for science in the classrooms of our teachers who are in the local in the public school system. However, Indiana does not include science in developmental testing. Poor performance in the local schools in the areas that are tested led the school district to focus on other subjects. Our workshop teachers from the public schools did not teach much science in the 2001-2002 academic year. However, the school district has now created an integrated science curriculum that will allow the teachers to spend more time doing science activities. We expect that our teachers will report that they are using the guided inquiry methods in their classrooms when we conduct our follow-up meeting later this year.

Future Plans

Although we knew we would convert many teachers to using guided inquiry, we never dreamed of the dramatic effect of this success. It is readily observable and easily assessed over the week of the class and is evident in our assessment based on our post-workshop meetings with many of the teachers. We have been so encouraged in this outreach effort that we have moved to include this guided inquiry curriculum into the required science course for our pre-service education majors at Saint Mary's College.

We have adapted a small piece of McDermott's well-documented research-based curriculum to create a very successful workshop experience as a type of outreach education for teachers in our area. We urge others to adopt our workshop methods and contribute to the paradigm shift for science education in all schools. We are certain that creative, innovative faculty can readily adapt this approach to teaching biological or earth science courses to pre-service and in-service teachers across all grade levels and can achieve the same success we have with our teachers. Materials in commercial kits can be used effectively with appropriate training and understanding of guided inquiry instruction so that all teachers can teach all their science curricula effectively in their classrooms.

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