ASSESMENT OF STUDENT SCIENTIFIC ATTITUDES AFTER TEACHER PARTICIPATION IN AUTHENTIC SCIENTIFIC RESEARCH

THESIS

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CHAPTER 1

INTRODUCTION

There is a general consensus among the science education community that one of the best ways to achieve scientific literacy is through the process of inquiry (NRC '96a). A significant question remains on how to insure that students are exposed to the process of inquiry.

Teachers are a critical keystone to education, and giving them the tools to be successful is vital for our society. Many teachers exhibit didactic, lecture-based approaches to teaching science as a result of high-stakes testing (Firestone, Monfils and Schorr '04). Didactic techniques can encourage a skewed view of how the scientific community accumulates and disseminates knowledge as well as discourage the intellectual process of inquiry. The didactic approach is often modeled to teachers, therefore, it behooves the science education community to encourage changes in instruction that will lead to more inquiry and a better understanding of how science works in the 'real world', or at least within the scientific community. One way to facilitate change in public school science teachers is through the outreach of universities to provide in-service training for teachers.

In-service programs for teachers are typically presented by the school district in one or two day workshops during the school year (NRC '96b). Presenters at these workshops generally lecture and perhaps demonstrate to teachers about how they can enact change in their classrooms. That change typically correlates to a program that administrators are familiar with and have a broad level of appeal to satisfy a large number of teachers within the district. These workshops are rarely content specific, and teachers often garner a cynical view of these workshops, as they do not satisfy current instructional needs for their individual classroom. One could infer the limited effectiveness of this approach by observing the performance of American students on international tests such as the Third International Math and Science Study (TIMSS). American students, while scoring above many other countries in science achievement, are still outdone by students in several countries, particularly those in Asia. Eighth graders on the United States placed ninth in science in comparison with all other countries who took the TIMMS (http://nces.ed.gov/TIMSS/).

A different approach to in-service professional development was taken by the Science/Math/Technology Educational Institute (SMTEI) at Texas State University (TSU) during six summers from 1997 to 2003. This innovative program invited teachers from all over the state of Texas to participate in eight weeks of authentic scientific research in a variety of fields. Applicants varied by gender, grade level taught, content area taught and years of teaching experience. Teachers were made aware of research projects being conducted at TSU during their application for SMTEI. Teachers ranked their top three choices for participation and based on input from the teachers and supervising research professors, they were assigned to particular research scientists' projects. Projects were primarily in the areas of biology, physics, chemistry, and computer science. Once teachers were placed into a research program, they were then immersed in the process of science. They spent their first days reviewing the literature and fine tuning their particular research focus within the program parameters. After teachers had an adequate background in their particular area of research, they began their observations and experiments in earnest. They used modern scientific equipment for observation and measurement, participated in scientific dialogue with professors and graduate students, experienced frustration and exultation with their projects as well as a variety of individual experiences within the program. Teachers were expected to write and present their findings at the conclusion of the 8 week institute, and as a result completed their experience with a comprehensive view of the scientific process within the scientific community, based on their actual experiences (Westerlund, Garcia, Koke, Taylor and Mason '02).

As an integral part of SMTEI, teachers were expected to take strategies of inquiry learned during the institute and incorporate them into their own classrooms. To help the teachers meet this expectation, they were given a $1400 stipend to purchase materials for classroom use. Follow-up interviews and classroom observations were conducted to evaluate to what degree the scientific process of inquiry was transferred into their classroom (Westerlund et al. '02). Multiple positive outcomes were observed, including increased content knowledge for teachers, changed student views of their teachers as practitioners of science as well as an increase in the number of students performing hands-on laboratory and inquiry activities (Westerlund et al. '02).

Purpose of Study

The purpose of this study is to evaluate student attitude data gathered from teachers who participated in the year 2000 SMTEI program. This study will report and analyze student surveys concerning student attitudes towards science. The Scientific Attitude Inventory II (Moore and Foy '97) will be used to quantify student attitudes towards science. Student surveys will be evaluated from the Spring of 2000 and the Fall of 2000, before and immediately after teacher participation in the SMTEI program.

Research Question

Are there significant changes in students' scientific attitude after their science teachers have participated in SMTEI research experiences?

CHAPTER 2

LITERATURE REVIEW

Professional Development Programs and Inquiry

In 1996 a landmark publication was released by the National Research Council. This publication, National Science Education Standards (NSES), established the direction that science education should progress in the United States. These comprehensive standards have the ultimate goal of all students achieving scientific literacy (NRC '96a).

A key component of the NSES is the concept of scientific inquiry. Scientific inquiry refers to the diverse ways in which scientists study natural phenomena and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (NRC '96a). The methods of inquiry have become a part of the science education lexicon and how science educators expect students to know and use science (NRC '96a). The NSES establishes what students should know and be able to do concerning science content and methods. The NSES also states that school districts should treat teachers as decision makers whose work includes opportunities for continual learning and networking (NRC '96a).

One way in which teachers increase their knowledge and practice of teaching is through in-service training sessions. Teachers often view in-service as an ineffective means of improving teaching. According to a 1985 survey, they ranked in-service training as the least effective source of learning (Smylie '85). A study by Little ('93) indicated that existing models of professional development were not adequate to achieve ambitious learning goals in science. These studies revealed a weakness of professional development in science teacher training.

The NSES Professional Development Standards states that science teachers should learn "science content through inquiry" (NRC '96a). In other words, in order for teachers to teach science by inquiry methods, they must be familiar or have training with scientific inquiry (NRC '96a). Furthermore, in order to emulate the research experiences of working scientists, teachers need total immersion in the scientific research experience (NRC '96b). The five year SMTEI project provided total immersion experiences, and as a result, teachers gained knowledge of science content and scientific processes through activities associated with inquiry (Westerlund et al. '02).

Authentic Scientific Research Experiences for Teachers

Authentic scientific research programs were used to familiarize teachers with the process of inquiry. Dozens of teachers and scientists collaborated in research within a diverse group of programs. Examples of these programs include the Maryland Collaborative for Teacher Preparation on Science and Mathematics Instruction (MCTP), the Future Teacher Research Project (FTRP), Science Teacher Research Involvement for Vital Education (STRIVE), Florida State Universities CO-

LEARNER program and the SMTEI. These programs involve teachers in authentic scientific research. While these programs use a variety of methods to achieve their goals, immersing teachers in the scientific method is crucial to all of them. These programs also fulfill the expectations of the NSES system standard B: *Policies that influence science education should be coordinated within and across agencies, institutions and organizations* (NRC '96a, p. 231). The effectiveness of a particular scientific research program for teachers is dependent upon creating a bridge between teachers and scientists (NRC '96b). The NRC states that programs that involve research scientists with teachers enable teachers to learn about scientific inquiry (NRC '96b).

The American Association for the Advancement of Science, (AAAS) in its publication *Science for All Americans,* (AAAS '89) identifies five features of scientific research as a mode of inquiry. The SMTEI used these features to validate that the participants were provided an authentic scientific research experience. All of the features were experienced, at least in part, by all participating teachers. Features that all teachers experienced included: 1) the development of an experimental design, 2) obtaining evidence by observation and measurement and 3) explaining the evidence based on valid observations (Westerlund et al. '02). Research scientists, as well as their graduate students, guided the teachers through all of these features. Experiments such as water quality assessment, fractionated crude oil tests, fire retardation studies and several others contained these authentic science features.

The MCTP program supports the idea that teachers must be adept at scientific inquiry if they are going to be expected to teach scientific inquiry. It stands to reason that if a teacher is not familiar with the process of scientific inquiry, he or she could not teach that process.

> *"It is generally agreed that what teachers believe in, as it relates to their philosophy of teaching, their role within that process, their role and expectations of the students for learning and the role of the school science curricula and context for instruction will be an essential foundation for what occurs in the classroom" (Blake '02 p. 59).*

Blake asserts, based upon his beliefs expressed in the previous quotation, that if teachers have experience in a didactic lecture-based approach to instruction, that is what will persist. If they have experience in the inquiry approach that is what will persist (Blake '02).

Professional development using authentic scientific research is one way to convey the importance and effectiveness of inquiry as a method to teach science. The best examples of professional development for science teachers include lab investigations that test hypotheses developed through teacher-scientist partnerships (NRC '96b). Research exists that show the positive effects of teacher/scientist collaborations as well as immersion of teachers in the actual processes of science. For example, the Future Teacher Research Program (FTRP) at the University of Arizona placed pre-service teachers into scientific laboratories and provided them the opportunity to expand their study of science and mathematics, operate scientific equipment and increase their understanding of the scientific method in action (Raphael, Tobias and Greenburg '99). As a result of these opportunities, FTRP participants reported five specific benefits. 1) The program increased the likelihood that participants would be able to communicate to their secondary students what professional mathematicians and scientists actually do. 2) Participants gained insights from the program that affected their pedagogical approach in the classroom. 3) Participants developed relationships with mentors that allowed them to see scientists as 'real people'. 4) Participants established relationships with the scientific research and teaching communities that could be called upon to enhance their teaching. 5) Participants learned and implemented pedagogical strategies as a direct result of the program (Raphael et al. p.155). Another example of the positive effects of immersing students in the scientific process can be seen in Florida State University's CO-LEARNERS program. This program also involved students in authentic research. Multiple positive effects of this program were reported by participants. First, that they gained science content knowledge through collecting data. Second, that they gained more self confidence by shouldering the added responsibility of the program. Finally, that they recognized the importance of mentoring of teachers by scientists to gain experience in making a difference in improving science education for in-service teachers (SERVE '02). Further, according to information gleaned from the MCTP, teachers' ideas about scientists and the process of science is naïve, and programs must facilitate questioning and the pursuit of understanding in order to dispel that naiveté. The research experience that these teachers engage in cause them to reflect on what they have learned and question and pursue understanding alongside their students. Teachers are expected to encourage curiosity in their students, as well as the intention to nurture their students' courage and persistence so that they will continue to construct their own knowledge and understanding (McCall-Ross and Demiston '02).

These examples illustrate the pattern that is called for in the NSES that identify a need for students to be able to experience the richness and excitement of knowing about and understanding the natural world through inquiry (NRC '96a). The research shows that having teachers who are competent and experienced with the scientific methods through their own personal research experiences are best able to convey those methods to their students. The process of inquiry is often littered with epiphanies that involve processes that can be crucial to the learning process. Several historical accounts of these thought-provoking legends persist in the common culture. Newton's apple, Edison's incandescent filament and Archimedes concept of displacement all represent legendary scientific epiphanies. Teachers in scientific research programs have had similar epiphany-like experiences while working with scientific tools or reading in scientific literature (Westerlund et. al. 02'; SERVE '02; Bazler '91). Teachers experienced the scientific process of discovery through their research and then transferred that process into their own classrooms. Perhaps programs which can encourage teachers to think like scientists will help those teachers' students think like scientists. This could lead to students experiencing their own epiphanies. According to one SMTEI teacher, "The kids get more excited when they are discovering things for themselves" (Westerlund et al. '02).

Evidence of Student Inquiry Experiences

The inquiry approach to teaching science was evident in teachers' classrooms after teachers participated in SMTEI. One high school teacher, during her SMTEI experience, made observations and measurements of fossilized leaves. She used these observations and measurements to make inferences about paleoclimate during the lifetime of those plants. This activity was then directly transferred to her classroom. Her students made collections and observations of leaves from a park close to an airport and made inferences about past climate in that area, with the assistance of their teacher and her cooperating SMTEI research scientist. The student predictions were then compared to local airport data to check their inferences. According to this particular SMTEI teacher "The research experience last summer added to my arsenal of activities that involve students directly and get them to think creatively". Another SMTEI teacher used funds provided by SMTEI to purchase materials to create a Winogradsky column, a self-contained bacterial ecosystem. Students used this Winogradsky column to monitor carbon, sulfur and nitrogen gas levels as well as temperature and pH levels of an artificial ecosystem. They also collected samples for staining and identifying bacteria as well as preparing graphs on two months worth of collected data (Westerlund et al. '02).

The inquiry approach to teaching science was also evident in classrooms of teachers who participated in a summer authentic research program at Lehigh University in Pennsylvania. After participation in the program, teachers introduced inquiry activities concerning steel degradation as well as a computerized pendulum activity. Furthermore, after their summer research experience, all teachers joined and participated in the Junior Academy of Science program (Bazler '91).

Effective Components of Professional Development Using Authentic Research

Effective strategies have been developed to establish what makes a professional development program successful. Some essential components of professional development are:

-Daily feedback in the form of journals and learning logs

-Participants work as scientists and write about science

-Participants conduct long-term investigations

-Provide funds to purchase supplies

-Follow up to encourage continued implementation

(Radford '98). These characteristics are conspicuous in the SMTEI program, and are no doubt contributors to the effectiveness of the program.

A benefit of the immersion technique for teachers is that it addresses the mismatch of teacher beliefs and the process of inquiry. Teachers often have an objective view of science that says science is a body of knowledge that is created by a rigid scientific method, as opposed to a constructivist view that says science is tentative and inventive in the formation and development of knowledge (Lynch '97, Prawat '92). Immersing teachers in authentic research confronts this mismatch, as they gain through practice the idea that science is constantly examining not only what we know but how we know it. This information is supported by more recent studies that confirm the idea that the professional development of science teachers must account for teachers existing knowledge, beliefs and attitudes and long-term professional development programs are needed to achieve long lasting change (van Driel, Beigaard, and Verloop '01).

The National Science Foundation GK-12 program, while not an example of immersion of teachers in authentic research, is an example of another method familiarizing teachers with inquiry. This program places graduate teaching fellows in math and science into partnerships with schools, universities and teachers to model, mentor and understand the processes of inquiry (Lundmark '04). Lundmark stated, in her review of NSF GK-12 programs that "Partners developed critical thinking skills and deepened their understanding of the process of science." (Lundmark, '04). The NSF GK-12 program has been for funded for 2006 which indicates continuing federal support for inquiry-based learning (NSF '06). This program may be viewed as an indicator, as the NSF has increased by 12.4% the amount of education and human resource funding dedicated to research, evaluation and communication, as well as three active programs funding science, technology, engineering and mathematics. (NSF '05).

Student Scientific Attitudes

It can be surmised that what and how teachers teach science can have definitive and lasting effects on student scientific attitudes and attitudes towards science. A notable aspect of measuring student attitudes towards science as well as student scientific attitudes is the difficulty and lack of continuity in instruments that measure scientific attitude (Coll, Dalgety and Salter '02). Few instruments exist to measure either student scientific attitudes or student attitudes towards science. *Attitude towards science* refers to what we think of science whereas *scientific attitude* refers to what we think we can do with science (Coll et al. '02). The predecessor of the instrument used in this study, the Scientific Attitude Inventory (SAI), is claimed by the authors to be used extensively on an international scale (Moore, Foy '97). The SAI II was created to remove gender bias, complexity in statements and a reduction in the number of statements (Moore, Foy '97). Questions have been raised about instruments that are used to measure attitudes towards science and scientific attitudes (Coll et al. '02; Munby '97). Questions about construct validity in the results of such instruments are persistent in the literature. Construct validity refers to whether a scale measures the unobservable social construct (scientific attitude, in this case) that it purports to measure (www.en.wikipedia.org/). In other words, are we really measuring student scientific attitudes, or are we measuring something else? The primary criticisms of the SAI II are the lack of theoretical grounding (whether or not the instrument is based on a legitimate concept) and a lack of validity (Coll et al. '02; Munby '97). Researchers often resort to creating their own scientific attitude measurements instead of using one of the few instruments available (Jarvis and Peel '05, Shymansky, Yore and Anderson '04, McGinnis, Kramer, Shama, Graeber, Dalgety, Coll and Jones '03, Parker and Watanabe '02).

It becomes evident after a review of the literature that multiple measurements of science attitude using the SAI II result in either no change or a negative effect (Ennis '05, Brannan '04, Bodzin and Cates '04, Burnley, Evans and Jarret '02). It is plausible that these examples indicate that student scientific attitudes are very difficult to change. It could also indicate a need for a more sufficient survey instrument combined with long term (multiple year) assessment to be done concerning scientific attitudes. The fact remains that although there are great difficulties surrounding the assessment of student scientific attitudes, it is something that remains an important learning objective in science and teacher training is critical in changing student scientific attitudes (Osborne '03).

Regardless of the doubts surrounding attitude measurements, a student's scientific attitude is conceivably an important component of their overall understanding of science. It is reasonable to expect that a student with a more positive scientific attitude will be more willing to learn and engage in scientific activities. More recent attitude surveys, such as the *Changes in Attitude about the Relevance of Science* (CARS) (Siegel and Ranney '03), as well as the extensive work by Norman Lederman and his colleagues into the nature of science will probably result in more effective instruments to measure components of scientific attitude. The CARS has more items and therefore can identify more specific outcomes, and it also contains three parts which are given before a treatment, immediately following a treatment and finally a duration of time after the treatment. This three level aspect could lead to a more complete picture of a students' scientific attitude. Ledermans' work in the field of the nature of science will likely lead to a more concise definition of what we are trying to measure when we study scientific attitudes. The current state of attitude measurement in science appears to be in a state of flux, and no one instrument has appeared to quell many of the questions concerning scientific attitude measurement.

Although the SAI II used in this study has some questions about its validity, it is considered to be reliable instrument. Reliability refers to an instruments ability to measure something consistently. Reliability can be assessed mathematically, and the SAI II has a Cronbach reliability of 0.781 (Moore and Foy '97). In the field of psychometrics, a Cronbach value over 0.700 is considered reliable (Paul Raffeld, personal communication, 12/11/05). This reliability indicates that the data about student attitudes is useful and can be indicative of any change that has occurred in students. In other words, since the instrument has a high reliability rating, we can be relatively sure that any change that occurs is a result of the treatment, and not of the test itself. Questions of validity, however, refer to whether or not the instrument measures what we think it is measuring. As mentioned previously, as the field of science education achieves a more homogeneous definition of scientific attitude, perhaps an instrument will be designed that is both reliable and valid.

The advantage of the SAI II is that it assigns a quantitative value to student attitudes. Current trends in education are focusing very strongly on quantitative assessment of student performance (NCLB '02) and attitude is considered a component of student performance. This quantification also allows for the ability to condense large amounts of data into an understandable value for statistical analysis (Bartz '88). This analysis can then be used to adjust instruction so as to maximize the positive change in students' scientific attitudes. Teaching through inquiry has been shown to improve scores on achievement tests and improved science process skills (Gibson and Chase '02). The research community in science education can endeavor to show, through quantitative analysis, if scientific attitudes exhibit positive change as a result of inquiry methods of teaching. If the research community can show how science attitudes change as a result of a particular treatment (such as SMTEI), then those treatments can be used in a multitude of settings and allow for growth and change in science education.

Conclusion

> *"Students will see the allure of science and feel the thrill of discovery, a greater diversity of intellects will be attracted to careers in science and an invigorated research enterprise will be fueled by a scientifically literate society."* (Handelsman, Ebert-May, Beichner, Bruns, Chang, Dehaan, Gentile, Lauffer, Stewart, Tilghman, '04).

This quote, taken from a recent article in the journal, *Science,* introduces the concept of scientific teaching. Scientific teaching is defined by Handelsman et al. as an inquiry based activity and echo the reform efforts called for by the NRC. Inquiry teaching needs to be a part of ALL science education, from kindergarten through college. Human beings have a natural proclivity to curiosity, and inquiry capitalizes on this inclination. In our ever changing world, knowledge of science and scientific methods will be critical to our survival. We ignore the strides of science at our own peril. More people on the planet are straining an already stretched environment. Society needs to have the tools to deal with this strain.

Adopting innovative and exciting teaching techniques such as inquiry will encourage more students to not only pursue careers in science but to be more scientifically literate. A more scientifically literate society will lead to a more effective society that can deal with the obvious hurdles we have ahead of us.

Logic and reason often seem in short supply and science does an admirable job of providing some logic and reason for society. We must give our teachers the tools in which to create a 'scientific society'. Immersion in the processes of science is one way to achieve that goal. These methods of inquiry recast the ideas of the famous educator John Dewey, who saw a need for modern students to acquire the 'critical habits of mind' that separate an educated populace from an ignorant one.

CHAPTER 3

METHODS

The original study of the Science/Math/Technology Educational Institute (SMTEI) by Westerlund et al. ('02) established multiple positive effects for teachers and students based upon qualitative data. Quantitative data were collected by the SMTEI research group but it had not been analyzed. I analyzed the quantitative data concerning student science attitudes that were collected from participating teachers of the year 2000 SMTEI.

Data Collection

The data consists of student responses to the Scientific Attitude Inventory II from the Spring and Fall of 2000. Not all teachers who participated in the summer of 2000 submitted usable data. Some teachers submitted scantrons which were unreadable by the testing center at Texas State University. Others did not submit all of the data requested. Some data that were submitted was mislabeled or not labeled at all, making it unusable. Thirteen out of nineteen of the teachers who participated in the year 2000 SMTEI submitted usable data.

SMTEI Teachers

These 13 teachers exhibited a variety of experiences while participating in SMTEI. These teachers also taught a variety of science content areas in their home districts including life, physical and earth sciences. Teachers either taught a combination of different science content areas or focused on one particular science content area. Nine of the participating teachers were female and four were male. Seven teachers taught at the high school level (grades 9-12). Six taught at the junior high level (grades 6-8).

Physical Data

The scantrons were housed for five years in the SMTEI office. Analysis of the data began in the fall of 2005. Data were recorded on CP23-0251 scantron forms. Teachers were assigned numbers, which were recorded on the scantrons so as to identify individual teachers. Students were surveyed in the spring of 2000 prior to their teachers' experiences in the SMTEI. These surveys were coded with the number five. The total number of surveys coded five is 1,327. Students were then surveyed the semester immediately following their teachers experience during the fall of 2000. The total number of surveys coded nine is 1,355. These surveys were coded with the number nine.

Specific information about student populations, other than population number, is unknown. The assumption is that the student populations that were surveyed before the teachers' experiences are different than the students that were surveyed after the teachers' experiences. This assumption is based on the fact that the population numbers are different, reinforcing the idea that teachers have gained and lost students from semester to semester. Typically, teachers get new classes every year, supporting the assumption that each year teachers gain a completely new student population.

Survey Instrument

The instrument used to quantify student science attitude for this study is the Scientific Attitude Instrument II, revised by Moore and Foy in 1997. The original Scientific Attitude Instrument was created over 35 years ago (Moore and Sutman '70). The instrument contained position statements representing the universe of content, namely attitudes toward science (Moore and Foy '97). Twelve position statements, six opposing positive and negative statements were developed. The position statements were intended to represent both intellectual and emotional attitudes. A pool of attitude statements was developed for each of the position statements. The attitude items were submitted to a panel of judges who judged each attitude statement with respect to whether it represented a particular position statement. The panel of judges consisted of four science educators, four practicing scientists, and two liberal arts science professors. On the basis of the judge's judgments, attitude statements were selected from the pool for use in the instrument (Moore and Foy '97).

Criticisms of the SAI were made by Munby ('83) concerning the validity of the instrument. Issues of validity are discussed further in chapters two and five. Criticisms concerning empirical support for the distinction between 'feelings' and 'beliefs' in a scientific attitude scale were raised by Nagy ('78). Nagy contended that vocabulary such as *phenomena, objective* and *idea-generating* were a cause for concern. Nagy also built a case for using a five-choice response format with an undecided or neutral category as opposed to the original four-choice format without a neutral category. The authors also recognized a need to remove gender biased terminology in order to make the instrument more equitable. Finally, the authors chose to make the instrument a 40 question survey as opposed to the original 60 question survey. No attempt was made to generate new statements. These concerns were addressed in the revision of 1997, resulting in the creation of the Scientific Attitude Instrument II (SAI II) (Moore and Foy, pp.329-330). The SAI II has 12 position statements. Six positions are positive and labeled 1-A through 6-A. Six are negative and are labeled 1-B through 6-B. The A and B pair for each position are opposites of each other. To clarify, statements 1A through 6A are positive. Statements 1B through 6B are negative. Each position statement, whether positive or negative, has associated attitude phrases to which respondents can agree with strongly, somewhat strongly, have no opinion, disagree somewhat or disagree strongly. The SAI II position statements and attitude statements are available in Appendix 1.

Data Analysis

The SAI II is coded by assigning point values to each of the attitude items. Point values are assigned as shown in Table 1. This study was concerned with total scores, which can range from 40-200 (1-5 points X 40 items).

Table 1
Point values for positive and negative items on the SAI II

	Positive Items	Negative Items
Agree strongly	5	1
Agree somewhat	4	2
Neutral/undecided	3	3
Disagree somewhat	2	4
Disagree strongly	1	5

The scantron forms were processed by the testing center at Texas State University. Raw scores were entered as an SPSS™ (Statistical Package for the Social Sciences) file (http://www.spss.com/). Mean student scores from the spring (pre-test) and fall (post-test) were calculated for each of the 13 teachers. The difference between student mean scores for each teacher was then calculated by subtracting post-test results from the pre-test results. This resulted in a negative difference if the post-test score exceeded the pre-test score and a positive difference in the pre-test score exceeded the post-test score. The average difference of the mean was calculated by determining the sum of all the differences and dividing by thirteen. Standard deviation was determined to measure the deviation from one data point to the next. Standard error of the difference of means was calculated to determine the variability of means. Standard error was calculated by dividing the standard deviation by the square root of 13. Raw effect size was calculated by dividing the mean difference by the standard error of the difference. This raw effect size can be used to determine if the results of the difference between pre-and post-test means is substantial and indicates an important change in teacher skills. A one-tailed paired t-test was used to determine whether or not the difference in mean scores from spring to fall is statistically significant.

Hypotheses

The null hypothesis for this experiment is that the mean difference from pre-test to post-test will be greater than or equal to zero.

The alternative hypothesis for this experiment is that the mean difference from pre-test to post test will be less than zero.

CHAPTER 4

RESULTS

Assessment of student scientific attitudes as measured by the Scientific Attitude Inventory II resulted in a slight positive increase from the Spring of 2000 to the Fall of 2000 for students of teachers who participated in SMTEI during the Summer of 2000.

Table 2

Mean scores and differences between spring and fall semester

Teacher	Spring 2000 Mean Score	Fall 2000 Mean Score	Difference
1	125.13	127.75	-2.61
2	140.78	144.33	-3.55
3	130.69	140.61	-9.91
4	128.79	130.77	-1.98
5	136.22	137.17	-0.95
6	128.40	132.92	-4.52
7	132.79	132.27	0.51
8	139.25	143.16	-3.91
9	136.73	140.29	-3.56
10	134.17	131.77	2.39
11	137.95	137.51	0.44
12	134.75	135.18	-0.43
13	137.32	136.87	0.44
Mean Value	134.16	136.31	-2.12

A one tailed paired t-test was use to determine if this increase was statistically significant. An alpha value of 0.05 was assigned for the t-test. The observed t-value is -2.54. The criterion t-value is 1.78. The results indicate that there was a significant change in student attitudes with a p-value of 0.0137. Quantitative analysis of SAI II survey data indicates that student scientific attitudes improved after their teachers participated in the year 2000 SMTEI. The results indicate that the null hypothesis is accepted, as the mean difference is greater than zero. The alternative hypothesis, that the mean scores would be less than zero is rejected. The raw effect size was calculated to be 2.54. This is a low effect size and could indicate that teacher skills did not improve enough to reflect a substantial change in student scientific attitudes according to the SAI II.

CHAPTER 5

CONCLUSION

A significant question remains in how best to create a 'scientifically literate' society. Does it involve Dewey's 'critical habits of mind' and methods of inquiry? Does it need to contain specific knowledge that ALL students must know as specified by the NSES? Can it be measured? How will it be measured? How will it be taught?

Obviously, the answer to the question of creating a scientifically literate society is complex and varied, but immersion of teachers in authentic scientific research has been shown to be effective in making science teachers' better practitioners of their craft (Westerlund et al. '02, SERVE '02, McCall-Ross and Demiston '02, Raphael et al. '99, Bazler '91). This type of professional development should become an important component of achieving scientific literacy for all. Universities, science teacher associations and individual school districts need to be aggressive in acquiring funding to support this type of professional development and pre-service training. Funding agencies such as the National Science Foundation need to not only continue but to increase their financial support of professional development and pre-service programs that immerse science teachers in authentic scientific research.

The SMTEI, and projects similar to it, shared the concept of immersing teachers in authentic scientific research. Benefits for teachers were far ranging and significant, primarily in terms of increasing teacher knowledge of content and processes associated with science practice. The SMTEI showed, through qualitative analysis, the benefit of immersing teachers in authentic scientific research. Teachers gained more content knowledge in science, practice in scientific skills and increased dialogue with practitioner of science. These gains transferred into their classrooms. Students gained a more realistic picture of how science is done by participating in increased laboratory based activities as well as witnessing the excitement about science that their teachers exhibit (Westerlund et al. '02).

The quantitative analysis resonates with similar positive results. The fact that student survey scores increased from Spring 2000 to Fall 2000 is quantitative evidence of the potential of SMTEI type projects, although the percentage increase in scores was small.

Significance of Study

This study demonstrates a small positive change, measured quantitatively, in students' scientific attitudes after their science teachers have had an authentic scientific research experiences which appears to be unique in the literature.

Summary

Multiple lines of qualitative evidence support the idea that immersing teachers in scientific research will make them more effective in their teaching practices. Now, at least one line of quantitative evidence supports the idea as well. Authentic scientific research as a type of professional development and pre-service preparation should become a consistent component of teacher training.

Teaching is ultimately about helping students. Providing science teachers with scientific knowledge and skills through immersion in authentic research will make them more effective in helping students achieve a more complete understanding of science. These students will certainly stand a better chance of being considered scientifically literate and fulfilling the goals of the National Science Education Standards set forth by the National Research Council.

Future Research

The methodologies used in this study could be improved. Improvements in the timing of when the surveys are given, for example, to allow for a full academic year between surveys would more effectively permit teacher practice to change as a result of the professional development. Additionally, a more sophisticated and valid instrument to measure scientific attitude should be developed.

APPENDIX

1 – A. The laws and/or theories of science are approximations of truth and are subject to change.

4. Scientists are always interested in better explanations of things.
16. Scientific ideas can be changed.
34. Scientists believe that nothing is known to be true for sure.

1 – B. The laws and/or theories of science represent unchangeable truths to be discovered through science.

11. When scientists have a good explanation, they do not try to make it better.
15. Scientists discover laws which tell us exactly what is going on in nature.
35. Scientific laws have been proven beyond all possible doubt.

2 – A. Observation of natural phenomena and experimentation is the basis of scientific explanation. Science is limited in that it can only answer questions about natural phenomena and sometimes it is not able to do that.

10. Scientists cannot always find the answers to their questions.
19. Some questions cannot be answered by science.
33. The senses are one of the most important tools a scientist has.

2 – B. The basis of scientific explanation is in authority. Science deals with all problems and it can provide correct answers to all questions.

2. Anything we need to know can be found out through science.
7. We can always get answers to our questions by asking a scientist.
26. If a scientist cannot answer a question, another scientist can.

3 – A. To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one's position on the basis of sufficient evidence.

17. Scientific questions are answered by observing things.
18. Good scientists are willing to change their ideas.
25. Scientists must report exactly what they observe.

3 – B. To operate in a scientific manner one needs to know what other scientists think; one needs to know all the scientific truths and to be able to take the side of other scientists.

3. It is useless to listen to a new idea unless everybody agrees with it
5. If one scientist says an idea is true, all other scientists will believe it.
32. Scientists should not criticize each other's work.

4 – A. Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects.

20. A scientist must have a good imagination to create new ideas.
21. Ideas are the important result of science.

28. Science tries to explain how things happen.

4 – B. Science is a technology developing activity. It is devoted to serving mankind. Its value lies in its practical uses.

9. Electronics are examples of the really valuable products of science.
24. A major purpose of science is to produce new drugs and save lives.
31. A major purpose of science is to help people live better.

5 – A. Progress in science requires public support in this age of science; therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work.

12. Most people can understand science.
23. People must understand science because it affects their lives.
29. Every citizen should understand science.

5 – B. Public understanding of science would contribute nothing to the advancement of science or to human welfare; therefore, the public has no need to understand the nature of science. They cannot understand it and it does not affect them.

6. Only highly trained scientists can understand science.
8. Most people are not able to understand science.
38. Scientific work is useful only to scientists.

6 – A. Being a scientist or working in a job requiring scientific knowledge and thinking would be a very interesting and rewarding life's work. I would like to do scientific work.

1. I would enjoy studying science.
27. I would like to work with other scientists to solve scientific problems.
30. I may not make great discoveries, but working in science would be fun.
36. I would like to be a scientist.
40. Working in a science laboratory would be fun.

6 – B. Being a scientist or working in a job requiring scientific knowledge and thinking would be dull and uninteresting; it is only for highly intelligent people who are willing to spend most of their time at work. I would not like to do scientific work.

13. The search for scientific knowledge would be boring.
14. Scientific work would be too hard for me.
22. I do not want to be a scientist.
37. Scientists do not have enough time for their families or for fun.
39. Scientists have to study too much.

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VITA

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