EFFECTIVE STRATEGIES FOR POSITIVELY IMPACTING STUDENTS' ATTITUDES AND INTEREST IN SCIENCE

by

Joel Kresse

A Project Submitted to the Faculty of

The Evergreen State College

In Partial Fulfillment of the Requirements

for the degree

Master in Teaching

2010

This Project for the Master in Teaching Degree

by

Joel Kresse

has been approved for

The Evergreen State College

by

Terry Ford

Terry Ford, Ph. D., Member of the Faculty

June 2010

ACKNOWLEDGEMENTS

I wish to thank everyone who has helped be along this journey.

- Thanks to all my MIT colleagues and friends for help researching, writing, editing, critiquing and relaxing.
- A special thank you to Sonja Wiedenhaupt for getting me headed in the right direction in my research and writing.
- Thank you to Terry Ford for editing this paper and helping me revise.
- Thanks to friends and family who have supported me throughout the process.
- One last thank you to all the researchers whose studies I reviewed.

ABSTRACT

Chapter one establishes the research purpose of discovering and building effective strategies for positively impacting elementary students' attitudes and interest in science. Creating positive attitudes is important because of their impacts on achievement and career interest. Chapter two provides a historical background establishing interest as a prerequisite to learning and motivation. Chapter three reviews research exploring trends in students' attitudes and evaluating the impact of various pedagogical approaches on attitudes. Research showed a decline in attitudes in science with age. Active, hands-on learning was popular with students. Integrated technology programs increased interest for some groups. Chapter four concludes the paper with a summary of findings, classroom implications and areas for further research. Integrating technology education into science creates a meaningful context for students. Incorporating cooperative learning will allow for building of relationships, sharing of interest and respectful communication between students. Curriculum should be relevant to students' personal lives. Teachers should expose their classes to female role models in science. Further research should focus on maturation and student perceptions of difficulty, cultural relevance and practicality.

TABLE OF CONTENTS

CHAPTER I: INTRODUCTION

Introduction

The purpose of this paper is to explore the various trends in the attitudes and interest of elementary students in science. Many issues about attitudes in science will be examined including the gender gap in attitudes, career interest in science and the dramatic change in attitudes in science between elementary and middle school. These issues will be discussed and analyzed with the focus of discovering effective strategies. With comprehensive evidence, I will attempt to discover and build effective strategies for positively impacting elementary students' attitudes and interest in science.

This research directly relates to classroom practice. I am searching for effective strategies that will inform my teaching of science. I want to learn how to draw the interest and enthusiasm of the diverse groups of learners that I will have in my classroom. To do this, I will examine research conducted with diverse student populations. I also want to discover strategies that are compatible with gender and racial equity so that each student has opportunities to learn and grow to his or her full potential. The effective strategies that I draw and build from this research will help to make science an interesting, approachable and fun subject in my classroom.

Using effective strategies for improving my students' attitudes in science is important to me because I think that science is an exciting, fascinating and useful subject. However, I know through personal experience that the subject can be presented in a very uninteresting and seemingly irrelevant manner. Since science is connected to many paths of study and professions, I feel that if children do not develop an enthusiasm for science, they will close many doors of opportunity. I want to keep those doors open, not to create a classroom of future scientists, but to help each child develop the skills, knowledge and positive attitudes to choose from a full range of future pursuits.

Rationale

Establishing positive attitudes toward science is important to the educational community as a whole because attitude and interest are closely correlated with achievement (Sorge, 2007, p. 33). The correlation between interest and achievement increases as students advance through elementary school (Denissen, Zarret & Eccles, 2007, p. 432). This correlation suggests that as students get older, they tend to achieve in the subjects that they enjoy. The interest-achievement correlation continues to grow stronger after elementary school in secondary schools (Schiefele, Krapp, & Winteler, 1992, p. 201). This makes the elementary years crucial for provoking and feeding student interest in science and other subjects.

Interest in science has the potential to be self-perpetuating Denissen et al. (2007) proposed that “a high level of interest in a domain may lead to an increased level of effort and persistence, resulting in higher achievement levels that may in turn reinforce the already high level of interest” (p. 443). This proposition suggests that interest, effort and achievement operate in a continuous cycle. I will work to improve my students’ attitudes and pique their interest in order to maximize their learning and achievement in science. My number one goal is for my students to learn as much as possible. I hope that if they have positive attitudes about subjects, including science, they will be more open to exploring and gaining knowledge in these areas.

Research indicates that students’ attitudes impact both the quality of their work in school and their opinions of classes and jobs in science (Pell & Jarvis, 2001, p. 847).

Studies show that students' perseverance in studying science in secondary school and beyond can be impacted by their middle school teachers' approach to science education (Koszalka, Grabowski & Darling, 2005). In selecting a career path, interest has been shown to be an important factor (Koszalka et al., 2005).

It is important to note that attitudes are not static entities. Researchers have found high levels of enthusiasm in elementary students that often decline as students grow older and enter secondary school (Nadirova & Burger, 2008, p. 31). Also, there is a disconnect between students' enjoyment of science and their desire to pursue science-related careers. Silver and Rushton (2008) found that although children hold positive attitudes towards doing science and about the benefits of science, these attitudes rarely translate into a desire to enter into scientific fields. In order to be effective, my strategies must improve students' attitudes in a sustainable manner.

The study of students' attitudes toward science is also relevant because of the gaps that exist between male and female students in terms of interest, experience, achievement and career interest in science (Hammrich, Richardson & Livingston, 2000). Many female students' interest and confidence in science decline during adolescence (Hammrich et al., 2000). Female students' perceptions of science as a masculine field can discourage interest in the subject and the pursuance of science careers (Hammrich et al., 2000).

Controversies

One controversy surrounding the topic of science attitudes is related to gender. Researchers have found conflicting results in their study of gender, attitudes and achievement (Nadirova & Burger, 2008; Sorge, 2007). For example, different studies have produced contradictory results about whether male or female students have more positive attitudes in science (Sorge, 2007, p. 33). Other studies indicate little to no relationship between attitudes toward science and gender (Nadirova & Burger, 2008). I will review numerous studies that analyze the impacts of gender and critique the practices of the researchers in order to determine which findings are plausible.

Another controversy exists between proponents of teacher-centered, direct instruction and student-centered, open instruction (Gläser-Zikuda, Fuß, Laukenmann, & Randler, 2005). Studies have found that while teacher-centered instruction can positively impact student achievement, it can also undercut students' motivation to learn (Gläser-Zikuda et al., 2005). On the other hand, research has shown that student-centered instruction can help create more independence in students, though the impact on achievement may not be as positive as that of teacher-centered instruction (Gläser-Zikuda et al., 2005). A combination of elements of the two approaches has been shown to improve student achievement and satisfaction (Gläser-Zikuda et al., 2005). Similarly, problem-based learning has been shown to have both benefits and drawbacks (Simons, Klein and Brush, 2004).

My recommendations for effective strategies are supported by professional literature in the field of science education. A combination of qualitative and quantitative studies gives me a well-balanced base of research. These peer-reviewed articles have been taken from professional, scholarly journals. Before proceeding too far, it would be beneficial to define some terms.

Definitions

When I talk about 'attitudes', I am referring to the interest and enthusiasm that result from students' experience with science and consequent perceptions of the field. "Interest" refers to students' desire to learn about science, while "career interest" denotes students' desire to pursue a science-related career. 'Students' in this paper are elementary and middle school age schoolchildren unless otherwise noted. 'Science' denotes all types including life, earth and space science. A "gender gap" is a disparity between male and female students in science interest, achievement, or career interest.

Limitations

I utilize a small body of research in this paper. Much of this research is specific to the studied student populations and cannot necessarily be generalized to other populations and situations. The conclusions that I make in this paper are tentative. More research will have to be conducted in order to solidify a core set of strategies for increasing positive attitudes in science. I am careful not to make broad generalizations based on studies that examine populations that are not representative of all children. I can only shed light on strategies that work for *some* teachers and students in *certain* instances. That being said, through this research, I can begin to glean some ideas and effective strategies from these studies while critiquing the studies and being aware of their limitations.

Chapter Summary

Chapter one has established a rationale for studying effective strategies for impacting students' attitudes in science. This research relates directly to classroom practice because I want to learn how to draw the interest and enthusiasm of the diverse groups of learners that I will have in my classroom. The links that have been found between students' attitudes and achievement make this research relevant to all teachers of science. Establishing positive attitudes is an important step in making sure that all male and female students can find success in science. Controversies exist about whether male or female students have more positive attitudes in science. My paper will explore these controversies in an effort to positively impact all students' learning.

Through my small body of research, I will glean some ideas and effective strategies, while critiquing the studies and being aware of their limitations. Chapter two provides a historical background of the study of students' attitudes and their impacts. Chapter three presents a critical review of literature in science education. The studies are both critiqued and mined for effective strategies for impacting students' attitudes in science. Chapter four concludes the paper with a summary of findings, classroom implications and suggestions for further research.

CHAPTER II: HISTORICAL BACKGROUND

Introduction

The discussion of students' attitudes has its roots in many important historical developments in educational psychology and philosophy. There is a very close link between student attitudes and interest. A history of the role of interest in educational thought and practice is very relevant to how researchers and educators measure, talk about and seek to improve interest and attitudes today. This chapter follows the ebb and flow of the study of the role of interest in education over the last 200 years. After early research on interest by Herbart and Dewey, a relative lull occurred during the prominence of behaviorism. A resurgence followed this lull as Bandura, Weiner and Dweck each studied the impacts of interest in education. Relatively recent research has explored possible reasons for the gender achievement gap in science. In the increasingly accountability-focused environment of education, interest has also become a political concern.

Early Research on Interest

German psychologist Johann Herbart (1776-1841) believed that interest should play a primary role in education (Spring, 2005). Herbart believed that a student must be interested in order to learn and thus teachers should try to evoke interest in their students (Nenniger, 1992, p. 121). He suggested that interest "leads to meaningful learning, promotes long-term storage of knowledge, and provides motivation for further learning" (Schiefele, 1992, p. 151). In the 1880s and 1890s, Herbart's theories were revived by members of the Herbartian movement (Spring, 2005). The Herbartians were the architects of the first class lesson plans, which were purposefully constructed to utilize student interest (Spring, 2005). These lesson plans worked to make students aware of their interests and the relation to the subject matter being studied (Spring, 2005). Herbart and the Herbartians views on interest "set the stage for child-centered education" (Spring, 2005, p. 272) in American schools.

Educational philosopher John Dewey further progressed student-centered education in America (Spring, 2005). Spring (2005) noted Dewey's revolutionary use of collaborative methods and his emphasis on student interest (p. 273). Dewey's emphasis on collaboration changed the social dynamic of his classrooms. The teacher was no longer the center of attention and the students had greater opportunities for expressing their ideas and following their interests. Dewey's ideas stemmed from a reaction to the rising industrialization of America (Spring, 2005). He thought that the movement toward an industrial society left behind family and community values (Spring, 2005). To supplement this loss, these values of "moral habits, industry, and social cooperation" (Spring, 2005, p. 274) would have to be taught in school. Interest played an important role in this student-centered education.

Dewey (1913) described interest as "evidence of the way in which the self is engaged, occupied, taken up with, concerned in, absorbed by, carried away by . . . subject-matter" (p. 90). Dewey linked interest with engagement and achievement. When a student is interested in a subject, the teacher does not need a hook. The student is hooked already. Dewey (1913) stressed the importance of engagement: "It is not enough to *catch* attention; it must be *held* [emphasis author]" (p. 91). This idea suggests that sustained engagement on the part of the student will improve student learning and achievement. Students may have some initial interest in a subject, but teachers must craft engaging curriculum that challenges students to question and explore. Dewey (1913) encouraged educators to create conditions that will allow for the expression of student interest and consequent engagement resulting in the “natural ends of achievement and efficiency” (p. 95). Following this heyday of research about interest, there was a general lull in the study of the topic for about 50 years (Krapp, Hidi & Renninger, 1992).

The Impact of Behaviorism on Education

Despite these early advances in student-centered education, the teacher-centered educational approach of behaviorism rose to the forefront of education in the early 20th century (Spring, 2005). The work of William James (1842-1910) and Edward Thorndike (1874-1949) “set the tone in education for several decades” (Spring, 2005, p. 277). The behaviorists believed that knowledge was a set of learned stimulus-response behaviors (Spring, 2005). Behaviorism calls for a teacher-centered approach in which the instructor arranges the classroom environment and events to stimulate the desired responses in the students (Huerta, 2009). The focus on teacher, rather than student, leaves little room for student interest and attitudes to play a role in educational planning and practice.

A Resurgence of Interest Research

In the second half of the 20th century, psychologist Albert Bandura explored the connection between society, personal cognition and motivation. Bandura’s social cognitive theory of motivation drew a connection between a learner’s thoughts and his or her motivation (Gettinger & Stoiber, 1999). The way that a learner perceives himself or herself and the subject matter has an impact on the student’s motivation to explore that given subject matter. If a student has a negative attitude about a subject such as science, he or she will not be motivated to engage in classroom activities. Bandura discovered that "personal evaluation and self-satisfaction function as powerful reinforcers" (Gettinger & Stoiber, 1999, p. 948) for learning. This finding suggests that a student who approaches a subject with enthusiasm and encounters some success will desire to learn more and more.

Psychologist Bernard Weiner also conducted research in interest, motivation and achievement. Weiner found that students who link feelings of effort with success are motivated to continue to put forth effort (Gettinger & Stoiber, 1999, p. 948). Students who believe in this link between effort and success feel in control of their own learning. In this context, a positive attitude means belief that greater effort will bring greater rewards. Weiner's research suggests that this positive belief empowers students to challenge themselves to succeed.

Carol Dweck was another social psychologist interested in the way that student conceptions impacted learning. Dweck and Leggett discovered that students who believe that effort fuels learning are more motivated than those who do not (Gettinger & Stoiber, 1999, p. 948). Dweck's findings are similar to those of Weiner. The key difference is that Dweck links students' conceptions of effort with their conceptions of learning, rather than success or achievement. Brophy and Dweck found that teachers can help feed students' intrinsic motivation by creating relevant tasks that offer flexibility, challenge and intrinsic rewards (Gettinger & Stoiber, 1999, p. 948). If these means are successful in piquing student interest, the student will be more likely to put forth the effort needed to learn.

Gender and Science

One researcher who has explored the history of the gender gap in science is Alison Kelly. Kelly (1981) presented several hypotheses that have been developed to explain the gender gap in science achievement. The "culture hypothesis" documented by Kelly suggests that society's lower expectations for female students in the subject of science manifest into lower achievement. Another explanation, the "school hypothesis" suggests that the manner in which science is presented in schools advantages male students over female students. A final hypothesis presented by Kelly, the attitude hypothesis, proposes that a disparity in male and female attitudes toward science has created the gender gap in science. According to this hypothesis, females do not achieve as well in science as males because they have less favorable attitudes toward the subject. Undoubtedly, many factors play a role in female students' attitudes toward science.

A student's conception of gender and the resultant strengths or weaknesses can also impact interest and motivation. In American culture, Hammrich found that many female students perceive science as a masculine field and as a result do not continue in future science education or occupations (Hammrich, Richardson, & Livingston, 2001, p. 6). Female students who do not believe that females can succeed in science will be less motivated and both learning and achievement will suffer as a result. In this sense, a female's positive attitude would be tied to the belief that female students can achieve at equal levels as their male counterparts in science study and careers.

Interest as a Political Concern

Student interest is also a political concern. The American Association for the Advancement of Science [AAAS] (1993) emphasized utilizing students' natural curiosity to fuel an avid exploration of science in its publication *Benchmarks for Science Literacy*. The AAAS (1993) state that teachers do not need to teach curiosity, because it is innate in children, they need only encourage and nurture it in elementary classrooms and beyond.

Similarly, the *Revised Washington State K-12 Science Standards* (OSPI, 2008) spoke of the need to offer students "experiences to spark and nurture their interests in science and technology" (p. 2).

Chapter Summary

Many prominent educational psychologists and philosophers have explored the role of interest in education. Herbart and Dewey pioneered research on interest arguing that interest impacts both motivation and achievement. After a lull in research during the era of behaviorism, Bandura, Weiner and Dweck each found impacts of interest on motivation in the context of education. Relatively recent research has explored the gender achievement gap in science with the aim of determining its causes and creating solutions to reduce this gap. As accountability has become an increasingly stronger focus in the domain of education, interest has become a subject of political concern.

Chapter one established a rationale for studying effective strategies for impacting students' attitudes in science. Chapter two provided a historical background of the study of students' attitudes and their impacts. Chapter three presents a critical review of literature in science education. The studies are both critiqued and mined for effective strategies for impacting students' attitudes in science. Chapter four concludes the paper with a summary of findings, classroom implications and suggestions for further research.

CHAPTER III: CRITICAL REVIEW OF LITERATURE

Introduction

The aim of this critical review of literature in science education is to better understand trends in students' attitudes toward science and examine the effectiveness of various pedagogical approaches in positively impacting these attitudes. First, the change in attitudes with age will be examined. Second, gender differences in attitudes will be explored along with the impacts of various interventions on interest and attitudes in science and technology. Third, attitudinal variables related to confidence will be explored, such as theory of intelligence, effort beliefs, autonomy, competence and social-relatedness. Fourth, a section on technology will investigate the impacts of technological experiences on attitudes toward science, interest in scientific careers and attitudes about gender competence in technology. Fifth, studies incorporating active or problem-based learning in science will be surveyed. Sixth, studies involving the impacts of social interaction and cooperative learning on the attitudes, perceptions and interests of students will be examined. Seventh, the attitudinal impacts of extracurricular science opportunities will be explored. Finally, a collection of studies focused on the impacts of discussion on attitudes in science will be reviewed. All reviews will examine and critique the researchers' methods in order to determine the reliability and generalizability of the findings.

Change with Age, Including the Middle School Transition

The following studies examine the impact of age on students' attitudes and interest in science. The varied designs range from a cross-sectional quantitative analysis of a large sample population to a longitudinal, qualitative analysis of 21 students with an in-depth examination of only four. Looking at both quantitative and qualitative studies will help to both find trends in attitudes and find possible factors they may be in play. Many changes in attitudes and interest with age are explored in these studies. These studies will provide ideas for positively impacting students' attitudes in a sustainable manner.

Pell and Jarvis (2001) developed and tested attitude to science scales with over 800 students from age five to eleven in England. The researchers developed an attitudinal questionnaire with three primary scales. *Being in school* was designed to measure attitudes to science, other subjects and school in general. *Science experiments* was structured to "measure feelings toward science experiments" (p. 849). *What I really think of science* was developed to allow students "to rate feelings about science as a school lesson and science in the outside world" (p. 850). The researchers conducted pre-pilot and pilot testing to improve and refine the attitudinal instrument.

The main study took place in the city of Leicester. Schools that participated in the study had been selected for a science inservice program because of substandard science programs determined by "under-performance in the national science tests (SATs), Office for Standards in Education inspection reports highlighting science as a weakness and/or lack of past science inservice provision for the school" (p. 851). A sample population of 978 Year 1-6 students (aged 5-11) completed the attitudinal questionnaire. The researchers analyzed the data for significance using t-tests, chi-square and ANOVA tests.

Using the computer was the most popular activity included in the questionnaire (mean = 4.79, on a five point scale). The researchers found that "while reading, writing and doing science experiments, are fairly popular activities, writing in science books is not so liked" (p. 852) (mean scores: 4.18, 4.03, 4.05, 3.54, respectively). According to the

Science experiments scale, "children appear to like the co-operative practical hands-on aspects of science where they choose equipment and find out what happens" (p. 853). Within the scale of *What I really think about science*: The researchers performed factor analysis to create three subscales 'science enthusiasm', 'social context' and 'science as a difficult subject'. They found "a strong correlation 0.45 ($N = 763$) between the 'science enthusiasm' and 'social context scales'" (p. 856).

Several trends were seen in the analysis of change in attitudes with age. The researchers found "the overall liking of school remains relatively stable over the primary years" (p. 853). In regard to science, "there is a clear trend, common to both boys and girls, to rate science as less difficult and less demanding as they get older" ($p < 0.01$, male mean scores: Year 1 = 11.59, Year 6 = 9.12, female mean scores: Year 1 = 11.47, Year 6 = 8.25) (p. 857). Further, "as the subject is perceived to be easier, enthusiasm for science declines" ($p < 0.01$, two-way ANOVA $F(1783) = 29173$) (p. 857).

Gender-specific differences over time were observed as well. One trend was "that the attitudes of boys towards coming to school (item 12) remain relatively static during the primary years, while those of girls show a marked rise" ($p < 0.05$, male mean scores: Year 1 = 3.76, Year 6 = 3.58, female mean scores: Year 1 = 3.77, Year 6 = 4.54) (p. 852). While both boys and girls showed significant correlations between 'science enthusiasm' and 'science as a difficult subject' in Year 1 ($r = 0.55$ and $r = 0.62$ respectively, $p < 0.01$), by Year 5 girls' enthusiasm scores were negatively correlated with difficulty ($r = -0.3$, $p < 0.01$).

In general, these findings suggest that students enjoy the more hands-on elements of science. Also, the correlation between the 'science enthusiasm' and 'social context scales' suggests that students who have a greater understanding of the place of science in society are more enthusiastic about the subject. Several age-related trends were observed by the researchers. Interestingly, as students got older and perceived science as being easier, their enthusiasm for the subject declined. This correlation does not imply causation, but merits further exploration. Despite a positive correlation between enthusiasm and difficulty in Year 1, by Year 5 girls' enthusiasm was negatively correlated with difficulty. This suggests that while Year 1 girls enjoy the challenge of science, Year 5 girls have become overwhelmed by the difficulty and their enthusiasm has waned.

The researchers strengthened their study by running pre-pilot and pilot testing of the questionnaire and refining it to be more precise and accessible. The study had the strength of a very large sample size. This makes their assessment more likely to represent average students. On the other hand, the study was only performed in schools with struggling science programs. This limits the ability to generalize these findings to other schools. Generalizability is also limited due to the failure of the researchers to provide demographic information for the students who participated in the study. Furthermore, the study examined age by observing different students at different grade levels. A longitudinal study may have provided more accurate data of changes in attitudes over time.

In their examination of schools with struggling science programs, the researchers found several trends. In general, the students in this large sample most enjoyed the active, hands-on activities in science. For both male and female students, the older students were, the less enthusiastic they were about school science. Interestingly, older students rated science as being less challenging, suggesting that difficulty was not a major factor in their loss of enthusiasm.

Shymansky, Yore and Anderson (2000) examined the impact of three years of a reform program on Grade 3 and 4 students' attitudes and achievement in science as well as awareness of science careers. The program, called Science: Parents, Activities and Literature (Science PALs), "focused on incorporating children's literature and parent partners using an interactive-constructivist epistemology as its base" (p. 1). The quantitative study used a comparative groups design.

The independent variable was the teachers' quality of instruction using Science PALs strategies as evaluated by the district science coordinator. Evaluation criteria included how well teachers utilized and challenged student contributions and incorporated literature and parent involvement into lessons. The researchers used the cumulative ratings of teachers for the first three years of program implementation.

Attitude, achievement and career awareness data were collected and used as the dependent variables in the researchers' analysis. To assess attitudes and career awareness, a questionnaire with a five position, four point Likert scale was administered. Student achievement was measured with data produced by science achievement tests administered in the Third International Mathematics and Science Study (TIMSS). The researcher collected data on each student's past three teachers in order compare the independent variable and dependent variables. Data was analyzed using ANOVA tests.

The researchers found "no significant differences in student attitudes, awareness or achievement among students experiencing different qualities of instruction as defined by the teachers' use of student ideas, children's literature, and parent partners" (Attitude toward School Science mean scores: High quality = 2.89, Middle quality = 2.98, Low quality = 3.09, $p = 0.316$; Science Careers Awareness mean scores: High quality = 2.55, Middle quality = 2.65, Low quality = 2.65, $p = 0.630$; Achievement [multiple choice] mean scores: High quality = 50.8, Middle quality = 51.0, Low quality = 50.4, $p = 0.826$; Achievement [open-ended] mean scores: High quality = 49.2, Middle quality = 50.1, Low quality = 51.6, $p = 0.466$) (p. 9).

Regardless of whether or not a teacher followed the Science PALs criteria, no impact was found on attitudes, awareness or achievement. Previous research conducted by the authors showed several benefits of the program. As noticed by students and the district science coordinator, teachers "paid more attention to student ideas in science . . . [and] began utilizing children's literature" (p. 9). Also, "parents responded extremely positively to their new roles as partners and students sensed this increased involvement" (Shymansky, Yore & Anderson, 1999; Shymansky, Yore & Hand, 2000, as cited by the authors, p. 9).

It is difficult to discuss a study with no significant results. The most obvious inference would be that the Science PALs program has had no impact on attitude, career awareness or achievement. However, before jumping to this conclusion it is important to consider other factors that could have contributed to the non-significant findings. The researchers suggested that non-significant findings for achievement may have occurred as a result of the achievement test not measuring the types of gains that students are getting as a result of the Science PALs program. For attitudes, they suggested that most students already had very positive attitudes. In terms of career interest, the researchers offered that perhaps more time than three years was needed to see an impact.

The researchers strengthened their study by using three years of teacher performance data for a quasi-longitudinal design. This approach gave a more accurate idea of each teacher's average level of instruction. The design allowed for each student's data to be linked to each teacher's instruction, successfully isolating the independent variable. Unfortunately, the attitudinal and career awareness instrument was not well described. It is difficult to analyze the validity of the researchers' instruments when they were not transparent about the contents. Another weakness in the study was the failure to provide demographic information for the student population, schools or district. This limited transferability and generalizability of the results.

While the study found no significant impacts, this does not mean that no impacts existed. It could be that the instruments used to measure attitude, achievement and career awareness were flawed. The results of previous studies performed by the authors suggested that the program had made impacts on teachers' practices and parental involvement. It is not clear if these impacts are translating into impacts on students. This study suggests that they are not, but the popularity and perceived success of the program convinced the researchers to continue studying the district and searching for impacts on students.

Reiss (2004) conducted a longitudinal, qualitative study of 21 students' attitudes toward science from the ages of 11 to 17. The students attended a secondary public school "in a semi-rural setting in the south of England" (p. 99). The researcher utilized an ethnographic design conducting annual interviews with the students at home and observing their science lessons at school. Over five years, the researcher observed 563 science lessons. In addition to student interviews, Reiss conducted interviews with "one or both parents, and each teacher, learning-support assistant, or student teacher who had taught classes during the year with any of the 21 students" (p. 99). The article focused on the changes over time for four students, two male and two female.

Questions asked during the interview included: "How have you found the science lessons so far?" and "What's the most useful think you reckon you learnt in science at (Pasmoor School)?" (p. 101). At the end of the end of the interview, the researcher asked the student for any additional comments. In the final interviews, conducted a year after students had finished their mandatory schooling, Reiss asked what the student thought of his or her science education in general and what attributes a secondary science education should have?

In general, students enjoyed experiments and the practical components of science. Most students did not enjoy writing in science. They desired practical subjects that were relevant to their daily lives. Students also desired teachers who took a personal interest in students and took time to explain subjects thoroughly. Despite originally being enthusiastic about science, several students lost their enthusiasm for science with age. The researcher explained that this trend was visible in the larger sample as well. Regardless of the waning enthusiasm for science, 60% of the 21 students planned to use science in career fields such as physics, psychology, electronics, biology and chemistry.

This admittedly subjective study of secondary students provides interesting insight for instructional practices. Students were clear about what they liked and did not like in science lessons. Most students preferred experiments to writing in science class. What students like and what they need may not always coincide, however, there is validity in their calls for relevancy in science instruction. While it is disconcerting to see students lose enthusiasm for science with age, it is understandable when they express frustration over a lack of relevant topics. It could be that creating a more relevant curriculum will help these students maintain the higher levels of enthusiasm in science that they had when they were younger.

The primary strength of this study was the longitudinal, qualitative design. This allowed the researcher to carefully observe change in a small group of students over seven years. Unlike a cross-sectional study that compared different students of different ages, this study showed real changes happening with individual students. The researcher also strengthened his study with member checks during the interviews to clarify students' answers. One weakness of the design was the failure of the researcher to provide demographic information for the students, thus compromising transferability. Another weakness is that some of the researcher's questions were vague. For example, many students would have trouble generating a specific answer due to the overly broad question of "What's the most useful think you reckon you learnt in science at (Pasmoor School)?" (p. 101).

Keeping the weaknesses of the design, limitations of the study and the fact that this study was performed with a secondary school population in mind, the students' responses do send some valid messages to elementary educators. Firstly, most of the students in this study lost enthusiasm for science with age. Second, the repeated requests for relevant, practical curriculum point to potential for enthusiasm in science. None of the interviewed students appeared to unconditionally dislike science. They disliked science that was not relevant to their lives.

Sorge (2007) assessed the differences in attitudes to science of students from age nine to fourteen including changes across the elementary-middle school transition in rural New Mexico. The participants in the study were 1080 students (595 female, 485 male) in "six elementary schools and three middle schools in two districts" (p. 34). The area in New Mexico where the study was conducted was 43% Latino, 14% Native American and 2% African American (incomplete racial data given) with 17% of people living below the federal poverty line. The quantitative study utilized a cross-sectional design to examine age, not a longitudinal design. Thus different children of different ages were compared. Data was collected near the beginning of the school year. Attitudes to science were measured with a survey containing 10 items. Students responded to statements such as "'Science is fun' and 'I would like to learn more about science'" (p. 34) on a five point Likert scale. Data was analyzed using two way ANOVA and the Games-Howell multiple comparison procedure.

The researcher found a significant relationship between age and attitude toward science (Science attitude mean scores: Age 9 = 4.9, Age 14 =3.42, $F(5,1068) = 46.88$, $p < 0.001$). There was a non-linear decline of science attitudes in the population with age. Students of ages nine, ten and eleven did not differ significantly from each other in attitudes (p value not given). Students of ages 12, 13 and 14 did not differ significantly from each other in attitudes either (p value not given). However, the two groups differed significantly from each other (Science attitude mean scores: Age 9-11= 4.84, standard deviation = 1.07, Age 12-14 = 3.73, standard deviation = 1.35, level of significance not given). The disparity between these two groups occurred during the elementary-middle school transition. The decline occurred with both male and female students. No significant differences in science attitudes were detected by gender (Science attitude mean scores: Male = 4.28, Female = 4.30, $F(1,1068) = 1.92$, $p = 0.167$).

It seems clear that students' attitudes toward science dropped between the elementary-middle school transition in this study. The study was not designed to determine why, it simply pointed out the results. Some combination of factors caused students to become less enthusiastic about science upon entering middle school. Gender was not found to be a significant factor in this drop in attitudes. The researcher did not speculate on reasons for the drop in attitudes, but she did suggest that further research should be conducted, particularly with attention to maturational or cultural influences.

A large sample size strengthened the findings of this study. The results were less likely to be anomalous or representative of only a small group. The cross-sectional design used did provide an examination of different students of different ages. However, a longitudinal study could have given more accurate data matching one group or more through the entire six year span studied. Another weakness of the study is that the attitude survey was poorly described. Thus the reader is unable to critique the quality of the attitudinal instrument. As admitted by the authors, the demographic composition of the sample population limited the generalizability of these results to a larger population. The authors suggested further study with other cultural groups as well as students who do not make the elementary-secondary transition at the same time.

This study did show an abrupt disparity in attitudes between students of ages 11 and 12. Though the demographic composition of the sample population limits generalizability, this elementary-middle school disparity in attitudes has been seen with other populations (Braund & Driver, 2005). Certainly, the many changes that occur during adolescence and the elementary-middle school transition could have an impact on attitudes toward science and to school in general.

Akerson and Hanuscin (2007) examined the impact of a three year professional development program on elementary teachers' and students' views of the nature of science (NOS). The professional development program involved monthly workshops and on-site support including model lessons, co-planning and mentoring. The qualitative case study followed three teachers (grade levels K, 1 and 5/6) who "each recognized science as their weakest instructional area" (p. 657) through a professional development program and assessed changes in their students. The authors, both former elementary teachers, conducted the professional development program as director (Akerson) and assistant (Hanuscin).

The study took place in a university town in the Midwestern United States. In the school, "the majority of the students are white and 29% qualify for free or reduced lunches" (p. 656). During the second and third years of the program, a selection of students from each class was interviewed at the beginning and end of each year using the VNOS-D questionnaire, modified for each grade level. The researchers also observed and video-taped science lessons in each class. Teachers were also interviewed at the beginning and end of each year, but the following analysis will focus on student interviews and impacts.

The researchers did not explicitly define "nature of science", but provided "six aspects of NOS believed accessible to K-6 students and relevant to their daily lives [:] . . . scientific knowledge is [1] both durable and tentative (subject to change); [2] empirically based (based on and/or derived from observations of the natural world); [3] subjective or theory-laden (influenced by prior knowledge and theoretical frameworks of the researcher); [4] partly the product of human inference, imagination, and creativity (involving the invention of explanation); [5] socially and culturally embedded (both influences and is influenced by the cultural milieu); and [6] utilizes both observation and inference" (Abd-El-Khalick et al., 1998, as cited by the authors, p. 655). For the purposes of independently analyzing data, "each researcher developed pre- and postintervention profiles of the NOS views of each participant for each year of the project, and these were compared" (p. 663).

In Carrie's kindergarten class, the 15 students interviewed showed little knowledge of target NOS ideas during the preliminary interviews. Some students (8) did show "a fairly good understanding of the distinction between observation and inference" (p. 666). Most students did not see a place for creativity in science. None of the students seemed to recognize the tentative or sociocultural nature of science. At the end of the year, some students had improved their views of the empirical and imaginative nature of science. Students showed no improvement in the areas of observations, inferences or the tentative nature of science.

In Charlotte's first grade class, of the eight students interviewed, some showed knowledge of the creative nature of science (3) and observations and inferences (4). Few understood the empirical (1), tentative (1) or sociocultural nature of science (0). After a year, students showed improvement in their views of the observations and inferences (6) as well as the empirical (3), creative (5), tentative (5) and sociocultural nature of science (3).

In Miranda's fifth/sixth grade class, ten students were interviewed. Students held misconceptions and had inadequate understandings of NOS components, particularly the imaginative, tentative and sociocultural nature of science. At the end of the school year, students "improved their views of the empirical, creative, and tentative NOS" (p. 672).

The professional development program helped these three teachers improve their students' NOS views. As admitted by the researchers, the older students seemed more developmentally fit to understand the NOS ideas. Some of the NOS ideas, presented at the beginning of this review, may be too abstract or complex for kindergartners or first graders. The workshops appear to be effective at the higher elementary levels. While the views of many students were successfully improved, no measure of impacts on other perceptions, attitudes or achievement was conducted. This would be a fruitful area for future research.

The researchers strengthened the study through triangulation combining their views with those of teachers and students. Interviewing students at the beginning and end of the year was another strength of the study. This design allowed the researchers to see change over time as a result of the impact of each teacher's instruction. On the other hand this design also had a negative impact on the results. Students at the end of the year were much more comfortable and willing to speak with the researchers, as admitted in the study. The students may have given more complete answers at the end of the year as a result of the natural maturational change of being more comfortable and self-assured.

Keeping the limitations of this study in mind, the program described did help the three teachers to improve their students' views of the nature of science. Their views became more complex and representative of the diverse nature of science. It is important to consider that not all students will be equally ready for complex ideas. It could be that an effective teacher tailors the knowledge and skills gained in professional development to fit his or her students.

Braund and Driver (2005) studied Year 6 and 7 students' attitudes to practical science in order to compare both sides of the KS2/KS3 (primary/secondary) transition. The study took place at a KS2 school and a KS3 school in the north of England. Practical science is not defined by the author, but was interpreted to mean experiments, investigations and other hands-on explorations in science. To determine attitudes to practical science, the researchers administered an open-ended questionnaire to Year 6 and 7 students. The researchers piloted the questionnaire with students and refined it. The refined questionnaire was administered to students by seven primary teachers and three secondary teachers near the end of November. One secondary teacher administered the questionnaire to three classes giving approximately even sample sizes of Year 6 and 7 students. The researchers could not explain a marked gender imbalance in the Year 6 sample.

The researchers' analysis involved coding students' responses to the questions: "Why do some people do practical science as part of their jobs?" (p. 22), "What is the same about practical science that people do in their jobs and the practical science pupils do at school?" (p. 23) and "What is different about practical science that people do in their jobs and the practical science pupils do at school?" (p. 24). Chi-square tests were used to test for significant differences between Year 6 and Year 7 students.

In response to the question 'Why do some people do practical science as part of their jobs?', significant differences existed between Year 6 and Year 7 students. Significantly more Year 6 students responded in the category of 'Testing products and/or things' (Year 6 = 12%, Year 7 = 5%, $p < 0.01$). Year 7 students were more likely to offer a response in the category of ‘To find out or discover something new (e.g. medicines and cures)’ (Year 6 = 33%, Year 7 = 49%, $p < 0.01$). In answering the question ‘What is the same about practical science that people do in their jobs and the practical science pupils do at school?’, significantly more Y6 students responded in the category of ‘Both do experiments or tests’ (Year 6 = 40%, Year 7 = 13%, $p < 0.005$).

When asked ‘What is different about practical science that people do in their jobs and the practical science pupils do at school?’, significantly more Year 6 students drew a distinction between purposes: for learning in school and for money at a job (Year 6 = 14%, Year 7 = 3%, $p < 0.02$). Year 6 students also responded significantly more in the category of ‘What scientists do has an impact (can change ‘the world’)’ (Year 6 = 10%, Year 7 = 3%, $p < 0.05$). Year 7 students saw work science as more dangerous than school science (Year 6 = 15%, Year 7 = 31%, $p < 0.005$).

These findings suggest that there are many differences between Year 6 and Year 7 students’ attitudes to practical science. In response to the question of why people do practical science in their jobs, more Year 6 students gave the concrete example of testing while more Year 7 students gave the more abstract answer of discovery. This could be an indication of more developed abstract thought. It is possible that Year 6 students have a more romantic perception of the scientific field (changing the world), while Year 7 students seem more aware of the more complex and advanced (dangerous) nature of scientific work. These inferences are only speculations of possibilities. However it is clear that differences exist between students on each side of the primary/secondary transition.

The researched strengthened the questionnaire by pilot testing it with a group of students and refining it. Another strength of the study was a thorough exploration of differences between responses in the study. The nature of the open-ended questionnaire may have resulted in more significant differences between Year 6 and Year 7 students. A Likert-scale questionnaire may have allowed for more precise and objective comparison of the two groups of students. Unfortunately, the researchers failed to include demographic information for the school or area studied. This limited the ability to generalize the results to a larger population.

The results of this study may be skewed due to the open-ended nature of the questionnaire and the subjective nature of coding. However, there did seem to be a clear disparity between Year 6 and Year 7 students' attitudes toward science. There are many possible reasons for this difference, but their exploration was not the focus of the study. The researchers conducted this study to inform "bridging work" between primary and secondary school, that is projects and other curriculum began in primary to continue on in secondary school.

Summary

Several researchers saw a loss of enthusiasm for science with age (Pell & Jarvis, 2001; Reiss, 2004; Sorge, 2007). This is certainly a point of concern for elementary and middle school teachers. Changes in attitudes are likely due to many factors, including some out of the teachers' control, but teachers can make changes to keep students interested. It could be that more relevant and interesting curriculum could help students regain and maintain their interest throughout their science education. The transition from elementary to secondary school appears to be particularly problematic for students' attitudes (Braund & Driver, 2005; Sorge, 2007). Perhaps the bridging work mentioned by

Braund and Driver (2005) could help to ease the transition and help students maintain positive attitudes.

Attitude, Interest and Gender

As mentioned in the introduction of this paper, researchers have found conflicting results in their study of gender, attitudes and achievement (Sorge, 2007, Nadirova & Burger, 2008). There is not a universal consensus about the general trends in attitudes and interest across genders. Kelly (1981) suggested that a disparity in male and female attitudes toward science may have created the gender gap in science. According to this hypothesis, females do not achieve as well in science as males because they have less favorable attitudes toward the subject. If this hypothesis is correct, improving female students' attitudes would improve their chances of pursuing and achieving in science. The following studies examine gender, especially the circumstances of elementary school girls in science. These studies evaluate the impacts of various interventions such as workshops, a gender-sensitive science program and technology education on interest and attitudes in science and technology.

Yanowitz and Vanderpool (2004) conducted two studies to determine fifth grade girls' attitudes about science, interest in science careers and perceptions of extracurricular science workshops. The goals of the workshops were "to motivate girls to consider career opportunities in science . . . [and] engage the girls in some type of experiential activity" (p. 355). Workshops primarily focused on "basic science domains such as animal behavior, biochemistry, biology, botany, entomology, microbiology, and wildlife biology" (p. 355).

The first study was a quantitative, one-shot case study of female students' interest in science careers and perceptions of workshops. The subjects of the study were 77 girls, mostly in the fifth grade, from rural, northeast Arkansas, primarily low to middle class. Information was distributed to principals and fifth grade teachers in 56 school districts to be given to all female, fifth grade students. Students were randomly assigned to seven, half-hour workshops out of 16 possible workshops. Before the workshops, students were asked to rate how much they liked science on a five-point Likert scale. A questionnaire was given to all students at the end of each workshop. The questionnaire asked about students' interest in science careers before and after the workshop and their perceptions of women in the field of science. It asked such questions as "Did coming to this workshop make you more interested in becoming a scientist? . . . [and] Do you think a lot of women usually become scientists?" (p. 355). The term "scientist" was modified to fit the particular workshop, for example "entomologist" for the entomology workshop.

The second study used a mixed methodology one-shot case study design with both open ended qualitative and yes/no quantitative survey questions to assess female students' perceptions of scientists. The subjects of the study were 56 girls, mostly in the fifth grade, from the same area as the first study. Again students were randomly assigned to workshops with similar goals as those in the first study. Before the workshops, students were asked the open-ended question "What do you think scientists do?" (p. 357). At the end of each workshop, a questionnaire was given to all students. The questionnaire asked about students' knowledge gained in the workshops about what scientists do with questions such as "Did the leader of the workshop talk about what scientists do? . . . [and] Did the leader of the workshop talk about any problems women might have if they want to be scientists?" (p. 357). Again, the term "scientist" was modified to fit the particular workshop. For both studies, data analysis was performed using paired t-tests and chi-square tests to determine significant differences.

In the first study, the researchers found that of the girls attending the workshops, "only 12% stated they wanted to be scientists as a career goal" (p. 355). The girls generally had a positive attitude toward science, in response to the statement 'I like science', with a mean score of 4.6 on a five point scale. This mean score is significantly higher than the midpoint of the scale (3) ($p < 0.001$). The researchers also found that "eighty-five percent of the workshops had significantly [*p*s < 0.005] more students agreeing the workshops increased their interest in that particular career than disagreeing with this item" (p. 356). In regards to students' perceptions of women entering scientific fields, "only 31% of the 13 science workshops showed a significant proportion of students agreeing that women typically entered the specific scientific career discussed in the workshop" (p. 356).

For the second study, responses to the open-ended question 'What do scientists do?' were analyzed and categorized. The researchers found that "fifty-five percent of the students generated statements that scientists engage in some type of general, nonspecific, study or learning . . . [and] 16% of the students focused on the fact that scientists *help people* [italics author]" (p. 357). Almost all students perceived the workshop leaders talking about what scientists do (93%), many perceived the discussion of educational requirements to be a scientist (65%) and 30% of students perceived the leaders talking about problems that women might face in entering the field of science.

The first study showed a positive attitude toward science in the sample population through the question asking students to rate how much they like science. It seems that most (85%) workshops were effective in increasing career interest in the field discussed for a significant majority of students. Perceptions of science as a male-dominated field seemed to exist with only roughly a third (31%) of the workshops having a significant majority of students agreeing that women entered the field discussed. Further intervention would be necessary for the remainder of the students to see a more complete role for women in science.

The second study dealt more with points covered in workshops than students' attitudes. That being said, the responses to the open-ended question 'What do scientists do?' indicated some general patterns of thought surrounding science. While many students had ideas about what scientists do, the reason for why scientists perform these actions was often absent from their explanations. This could be due in part to the fact that there was no "why" in the question, but still points to an incomplete understanding of scientists.

The researchers strengthened their studies by providing demographic information about their subjects such as income level and school location. They also described how students came to be in the workshops (voluntarily, through information received at school). Unfortunately, the weaknesses of the studies severely limit the conclusions that can be drawn from the results. A pretest/posttest design would have strengthened the findings. Instead of simply asking students if their interest had increased as a result of the workshops, a pretest and posttest could have shown that their interest had changed. In this way the actual interest and change would have been measured, rather than a perceived change in interest. A control group was not used in either study. Therefore it is difficult to attribute the results to the workshops rather than the unique nature of the groups studied.

Regrettably, due to the weaknesses in the design of this study, there is very little that can be drawn from its results. Findings such as "only 12% stated they wanted to be scientists as a career goal" (p. 355) are not quantified by what proportion of students desiring a career in science would be either typical or desirable. How many students, female students in this case, can be expected to want to become scientists? The 12% given is meaningless without comparison to an average or a desired proportion. The positive attitude toward science found in the first study is not surprising considering that the students came to the workshops on a voluntary basis. Perhaps workshops are effective in increasing career interest in science, but more rigorous study is needed to show this connection. Whether or not workshops and experiential activities can improve female students' attitudes in science and interest in science careers is not shown by this study.

Cady and Terrell (2007) examined the impact of the integration of computing technology in science curriculum on the self-efficacy and attitudes of female, fifth grade students. The researchers used a quantitative, nonequivalent control group design over eight weeks. One fifth grade class was randomly selected as the experimental group. This group received science instruction that integrated computing technology. Another fifth grade class was randomly selected as the control group. The control group received science instruction and instruction in computing technology independently of each other. For example, during the second and third weeks the experimental group created and presented science-based multimedia presentations on computers. The control group also created and presented multimedia presentations on computers, but they were not related to science. The female students in both classes completed the Young Children's Computer Inventory at the beginning and end of the eight week intervention period. The inventory measured six subscales. The researchers defined self-efficacy as the combination of computer importance and enjoyment. They combined students' scores on the scales of computer importance and computer enjoyment to form scores for self-efficacy. The researchers analyzed the data for significant differences in mean scores between the control and experimental groups using a series of independent and dependent sample t-tests.

The pretests showed that no significant differences existed between the female students in the experimental and control groups in computer importance ($p = 0.766$), enjoyment ($p = 0.544$) or self-efficacy ($p = 0.551$) (Experimental group mean scores: Computer importance = 20.79, Enjoyment = 17.64, Self-efficacy = 38.42; Control group mean scores: Computer importance = 20.50, Enjoyment = 17.00, Self-efficacy = 37.50). The posttests revealed that female students in the experimental group had significantly higher feelings of computer importance ($p = 0.007$) and self-efficacy ($p = 0.011$) than the control group (Experimental group mean scores: Computer importance = 22.21, Self-efficacy = 40.43; Control group mean scores: Computer importance = 18.58, Self-efficacy = 35.83). The experimental group also had a higher posttest mean score in computer enjoyment than the control group, but the difference was not statistically significant (Experimental group = 18.21, Control group = 17.25, $p = 0.183$).

The findings of this study suggest that integrating technology instruction into science instruction may help improve female students' perceptions of computer importance and self-efficacy. Integration could positively effect computer enjoyment as well, although this remains to be seen. Perhaps integration makes the study of computers seem more relevant and practical to female students. Studying computers and science in isolation could make both subjects seem less important. Before accepting these inferences, the strengths and weaknesses of the study should be examined.

A pretest/posttest design strengthened the study. The pretest established base-levels of attitudes and self-efficacy. The posttest allowed for the observation of changes and the comparison of the attitudes in the experimental and control groups. By using a control group, the researchers isolated the variable of integration. Both classes experienced similar lessons with the only major difference being integration. Some weaknesses were present in the study. Demographic information for the sample population was not given (race, socioeconomic status, school location, etc.). This limits the ability to generalize these findings to apply to different student populations. Also the sample sizes in the experimental and control groups were very small, 14 and 12 respectively. Including more students in the sample populations would have strengthened the findings.

In their study of two classes, over an eight week time period, the researchers found that the integration of technology into science curriculum resulted in significantly higher levels of perceived computer importance and self-efficacy for female students than teaching the subjects independently. While these findings are significant, the small sample size limits the ability to generalize. The study should be repeated with a larger sample population in order to strengthen the findings. This study was done with a small sample and each group of students is unique.

Hammrich et al. (2000) evaluated the impacts of the Sisters in Science (SIS) program on minority, fourth grade girls' interest and achievement in science and mathematics in inner-city Philadelphia. The SIS program consisted of "(1) an in-school constructivist and gender-sensitive science program; (2) an after-school enrichment program; and (3) a 'city rivers exploration' summer camp" (p. 212). The program focused on providing a safe environment, gender-sensitive approaches, culturally relevant instruction and inquiry-based learning. The in-school program was conducted once a week for two hours and focused on science and mathematics applications in the urban environment. The after-school program was conducted once a week for 90 minutes and contained extensions of in-class activities and opportunities for reflection. The two-week summer program focused on creating plans for cleaning up urban rivers and included four field trips.

The quantitative study used a pretest and posttest and used the boys in the classes as a sort of comparison group. Approximately 256 girls and 194 boys participated in the study (numbers from posttest, pretest: 229 girls and 185 boys). A 30-item questionnaire was used to measure students' "attitudes about, interest in, and awareness of science and mathematics" (p. 214). The pretest and posttest questionnaires were conducted near the beginning and end of a school year respectively. For achievement measurement, "science process skills and mathematics skills instruments specific to the fourth grade and tied to the curriculum for fourth graders in the Philadelphia Schools were employed" (p. 214). The researchers used ANOVA tests to analyze the attitudinal and achievement data for significant differences between pretest and posttest scores and between girls and boys.

The researchers found no significant change in girls' pretest and posttest attitudes (Science attitude mean scores: Pretest = 3.88, Posttest = 3.96). They suggested that this lack of improvement could be due to relatively high attitudes held by girls at the beginning of the program. Gender differences did exist between the attitudinal scores. Girls' attitude scores were significantly higher than boys on both the pretest and posttest questionnaires (Female science attitude mean scores: Pretest = 3.88, Posttest = 3.96; Male science attitude mean scores: Pretest = 3.45, Posttest = 3.46, $p < 0.05$). On the skills posttest, girls and boys had significantly ($p < 0.001$) improved scores on the skills of observation, observing and predicting, classification and recognition of variables (Female pretest/posttest mean scores: Observation = 4.46/4.60, Observing and predicting = 3.43/3.72, Classification = 3.00/3.28, Recognition of variables = 2.95/4.46; Male pretest/posttest mean scores: Observation = 4.41/4.48, Observing and predicting = 3.28/3.74, Classification = 2.71/3.12, Recognition of variables = 2.98/4.40).

The study suggests that female students already had positive attitudes before the implementation of the program, more positive than their male peers, in fact. No attitudinal impacts were observed as a result of the implementation of the program. Whether this is attributable to relatively positive attitudes before the implementation of the program or not, cannot be determined without further study. Gains on the skills test suggest that the implementation of the program could have had an impact on both boys and girls skills. It is important to consider the strengths and weaknesses to determine the strength of this connection.

The pretest/posttest design allowed the researchers to examine attitudes and skills before and after the program implementation. Although the boys served as a sort of comparison group, there was no control group present in the study. Unfortunately, this missing component greatly weakened the study. The researchers had no way to determine whether gains in skills occurred as a result of the SIS program or just as a result of the rest of the school curriculum. The variable was not isolated.

Due to the lack of a control group, it is impossible to say that the SIS program was responsible for the impacts on skills observed in the posttest. The impacts could have resulted from many other factors. If the researchers could show significant gains compared to schools that did not participate in the SIS program, it would be clearer what the direct impacts of the program were. A redesigned study using a control group would help achieve these strengthened findings.

Mammes (2004) studied the impact of a technology education program on the technological interest of third grade girls and boys in Germany. A quantitative, nonequivalent control group design was utilized with two classes serving as the control group and two serving as the treatment group. Technological interest was measured through a survey given to students three times. The survey measured “various indicator variables such as ‘Frequency of dealing with the object’, ‘grade of popularity in dealing with the object’, ‘level of knowledge and orientation’ and ‘cognitive knowledge’” (p. 95-96).

The pretest was given to students in November, immediately prior to the administration of the treatment. The treatment was divided into two units. The first unit consisted of 16 hours over three weeks. It focused on studying and constructing electrical circuits to light a Christmas tree. Five weeks later, the second unit was conducted in 18 hours over six weeks. It involved the design, creation and efficient production of nesting boxes. The first posttest was administered after the second unit and a second posttest was given 12 weeks later. Data was analyzed for significant differences using t-tests and a Kolomogorov-Smirnov-test.

The pretest revealed that treatment group boys had a significantly higher technological interest mean score than treatment group girls (Male = 87.70, Female = 63.19, $p \leq 0.05$). The first posttest showed that both treatment group boys’ and girls’ technological interest scores increased significantly (Pretest/Posttest 1: Male = 87.70/92.07, Female = 63.19/76.90, $p \leq 0.05$). These levels of interest were maintained through the administration of the second posttest (Posttest 1/Posttest 2: Male = 92.07/93.80, Female = 76.90/76.75). Although treatment group boys continued to have a higher level of technological interest than treatment group girls, the gap between them diminished significantly by the time of the first posttest (Male – Female Pretest difference = 24.51, Male – Female Posttest 1 difference = 15.17, $p \leq 0.05$). No significant changes were observed in the control group over the study period (Control group mean scores for Pretest/Posttest 1/Posttest 2: Male = 78.91/78.20/77.70, Female = 64.79/66.80/65.10).

The findings of this study suggest that technology education can have a positive impact on both male and female students' technological interests. This impact may help to close the gap in technological interest between girls and boys. The treatment group experienced positive shifts in attitude for boys and girls and a diminished gender gap, while the control group experienced neither of these changes. It could be that a technology education program like the one given in this study could have the positive impacts on interest observed in this study. The strengths and weaknesses of the study will be examined in order to evaluate the strength of its findings.

One strength of this design was the use of a pretest and posttests. In addition to the ability to observe change over time, the second posttest allowed the researcher to see if the impacts observed in the first posttest lasted for an additional twelve weeks. Another strongpoint of the study was the use of a control group. The control group negated natural, maturational changes that may have affected technological interest over the study period.

The researcher limited the generalizability of her study by failing to adequately describe two components. First, the demographics of the sample population were poorly described. No race, class, or location information was given concerning the students involved in the study. Second, the survey instrument was poorly described. It was not clear how the researcher measured interest in the study. Another weakness of the study was the representation of causal relationships. The researcher stated “Overall, the result of the research study is that early encounter exposure to technology education at school leads to higher level of technological interest of both girls and boys that enables them to cope better with technology in everyday life” (p. 98). The causal relationship drawn in this statement is not supported by the findings of the study. It is only a possibility and should be represented as such.

The study does contain some useful information. It could be that a technology education program could improve technological interest in elementary students. That being said, unfortunately, the weaknesses of this study limit its applicability. Since very little about the demographics of the sample population was described, generalizability is difficult. Also, the lack of description of the survey instrument compromises the validity of the study. Findings cannot have much merit unless how they were determined is described.

Summary

These studies offer some interesting ideas for positively impacting both female and male students’ attitudes and interest in science and technology. Workshops provided extracurricular opportunities for female students, though the Yanowitz and Vanderpool

(2004) failed to quantify what these impacts may be. Although no attitudinal impacts were observed, the Sisters in Science program, focused specifically on female science education, may have contributed to an increase in science-related skills (Hammrich et al., 2000). However, the lack of a control group makes it difficult to draw this connection. Boosting technological interest and self-efficacy through the use of technology education and integration seems to be a viable option for some student populations (Cady & Terrell, 2007; Mammes, 2004). However, it is difficult to generalize how effective such programs will be in dealing with other, more diverse groups of children. Continued research of approaches to help female students develop positive attitudes and interest in science is needed.

The Role of Confidence

The following studies have been grouped loosely as the attitude of confidence. They represent related attitudes and feelings. Blackwell, Trzesniewski and Dweck (2007) examined students' theories of intelligence and effort beliefs. Theory of intelligence refers to whether a student considers intelligence a fixed entity that one is born with or a changeable characteristic that can be developed with work. Effort beliefs refer to how students view effort, as a sign of strength or weakness. Kunter, Baumert and Köller (2007) examined the impacts of classroom management on students' interest and motivational variables of autonomy, competence and social-relatedness. Examining the findings of these studies will glean effective strategies for increasing students' confidence and related attitudes.

Blackwell et al. (2007) conducted two studies to analyze the impact of theories of intelligence on junior high school students' achievement in mathematics. The two studies will be discussed independently in this section. The first study was a five year, quantitative, correlational study. Four successive, incoming classes of seventh graders were assessed. The sample of "373 students (198 females and 175 males) . . . were 55% African American, 27% South Asian, 15% Hispanic, and 3% East Asian and European American" (p. 248). The students were "moderately high-achieving, with average sixth-grade math test scores at the 75th percentile nationally; 53% of the participants were eligible for free lunch" (p. 248-249). For achievement data, mathematics grades for fall and spring term in seventh and eighth grade were collected. Previous math achievement information was collected from standardized math tests taken in the sixth grade.

To obtain data on theories of intelligence, the researchers administered a questionnaire to incoming students in the fall that measured "key motivational variables, including implicit theories of intelligence, goal orientation, beliefs about effort, and helpless versus mastery-oriented responses to failure" (p. 249). The implicit theories of intelligence subscale determined where each student fit on a six-point continuum of intelligence theory. An entity theory of intelligence (intelligence is a natural, unchangeable entity) was on one end of the scale, while an incremental theory of intelligence (intelligence is a changeable attribute that can be developed) was on the other. The "effort beliefs" questions measured how the students interpreted effort, for example "'The harder you work at something, the better you will be at it' . . . [vs.] 'If you're not good at a subject, working hard won't make you good at it'" (p. 250).The researchers used chi-square tests and t-tests to analyze the data.

The researchers found a positive correlation between incremental theory of intelligence and positive effort beliefs ($r = .54$, $p < 0.01$), low helpless attributions ($r =$

.44, $p < 0.01$) and positive strategies ($r = .45$, $p < 0.01$). In relation to achievement, the researchers found that "an incremental theory of intelligence at the beginning of junior high school predicted higher mathematics grades earned at the second year of junior high school ($\beta = .17$, $t = 3.40$, $p < .05$). A graph of theory of intelligence scores one standard deviation above (incremental theory) and below (entity theory) the mean compared with achievement data showed that "students with the entity and incremental theories did not differ significantly in their math achievement test scores as they entered junior high school . . . [but] began to pull apart over the 2 years of junior high school" (p. 251).

The correlations between incremental theory of intelligence and positive effort beliefs, low helpless attributions and positive strategies suggest close connections between theory of intelligence and these variables. The study does not discuss correlations between entity theory and these variables, so little can be said in comparison. Students who possessed an incremental theory did eventually outperform their peers who held entity theory beliefs. These groups, one standard deviation above or below the theory of intelligence mean, did begin to separate in mathematics achievement with an approximately 5% difference in scores by spring of eighth grade. This finding suggests that an incremental theory of intelligence may have a positive impact on achievement in mathematics, though the correlational study is not set up to draw causal connections. Examining the strengths and weaknesses of this study is relevant to the validity of its findings.

The researchers strengthened their study by observing four consecutive classes of students. This examination of multiple years allowed the researchers to collect more accurate data. Demographic information was included in the study to help the reader determine the potential for generalizability of the results to other populations. The questionnaire was well-described by the authors yielding understandable and believable results. One weakness in the study was in the analysis. There was a clear bias toward examining the incremental theory of intelligence. Correlations for an entity theory of intelligence were not shown. Therefore much was said about the correlations between incremental theory and motivational variables, but there is little quantitative comparison between the correlations of incremental theory and entity theory. Despite this absence, the researchers claimed that students holding an incremental theory "affirmed learning goals more strongly, and were more likely to believe that working hard was necessary and effective in achievement" (p. 253) than students holding an entity theory. This claim is not necessarily untrue, but the authors do not provide the quantitative evidence to back it up.

It could be that theory of intelligence impacts achievement and is related to a host of motivational variables. It appears that an incremental theory of intelligence is somewhat closely correlated with positive effort beliefs, low helpless attributions and positive strategies. Perhaps encouraging an incremental theory of intelligence could have a positive impact on achievement and these motivational variables. However, from the analysis, it is difficult to say what correlations exist between entity theory and these variables or compare correlations between theories. Despite a rigorous research design and sound methods, the one-sided analysis does not allow for the comprehensive comparison of the impacts of the two theories of intelligence. The second study further examined the interaction between theory of intelligence, achievement and motivational variables.

Blackwell et al. (2007) conducted a second study to assess the impact of an intervention teaching incremental theory to students on achievement in mathematics and motivation. A quasi-experimental, nonequivalent control group design was used in the study. The sample population consisted of 91 seventh grade students at a public junior high school in New York City (a different school than the first study). The students "were 52% African American, 45% Latino, and 3% White and Asian . . . [and] were relatively low-achieving, with sixth-grade math test scores at the 35^{th} percentile nationally" (p. 254). In regards to socioeconomic status, 79% of students qualified for free lunch.

The same theory of intelligence questionnaire used in the first study was given to all students in the fall term of seventh grade. Also, the same measures of achievement were used: sixth grade math test scores and math grades for fall and spring of seventh and eighth grade. Both the experimental and control group took part in workshops about "the physiology of the brain, study skills, and antistereotypic thinking" (p. 254). The experimental group also received explicit instruction in incremental theory explaining that intelligence is a malleable trait. The 25-minute workshops were conducted once a week for eight weeks during the spring term of seventh grade.

A quiz was given to students after the completion of the last workshop to test for the recall and comprehension of information. The theory of intelligence questionnaire was administered again, three weeks after the last workshop. The researchers asked the math teacher "to cite in writing individual students who had shown changes in their motivational behavior in the spring term (after the workshop), and to describe these changes" (p. 255). The teacher was unaware of which group (experimental or control) each student was in. The researchers used chi-square tests, paired sample t-tests and ANOVA tests to analyze the data and find significant differences over time and between the experimental and control groups.

The researchers found that "participants in the experimental group . . . endorsed an incremental theory more strongly after participating in the intervention (4.36 preintervention vs. 4.95 post-intervention, Cohen's $d = .66$, $t = 3.57$, $p < .05$)" (p. 256). Students in the control group experienced no significant change in incremental theory endorsement (Preintervention = 4.62, Post-intervention = 4.68). The experimental group was found to have significantly higher incremental theory scores (Experimental = 4.95, Control = 4.68, $p < 0.05$). In regard to motivational changes observed by teachers, "27% of students in the experimental group were spontaneously cited by their teacher as showing positive change, compared with only 9% of those in the control group" (p. 256). This difference was found to be significant ($p < 0.05$). The whole sample showed a significant decline in math grades between spring of sixth grade and fall of seventh grade (Spring = 2.86, Fall = 2.33, $p < 0.05$). After the intervention, the control group's grades significantly decreased again (no mean scores given, $p < 0.05$), while the experimental group experienced a slight gain in grades (no mean scores given).

In this study, the workshops appeared successful in significantly increasing the growth of incremental theory in students. It seems possible to develop incremental beliefs in students by explicitly teaching incremental theory. The experimental group experienced such a change, while the control group did not. A relatively brief intervention (eight 25-minute sessions) had a significant impact on theory of intelligence beliefs. The intervention may have had a significant impact on motivation as well, according to input from the students' math teacher. The last finding discussed in the section above suggests that the decline found in many students in math achievement in junior high school may be able to be halted by an intervention that teaches incremental theory. The core beliefs of incremental theory seem to have a positive impact on students that becomes observable in their behavior and achievement in mathematics class.

This study was strengthened with the use of a control group. For example, the lack of significant difference in incremental theory beliefs in the control group shows that the significant improvement in the experimental group occurred as a result of the treatment and not some other maturational change during the study. The use of motivational and achievement data collected multiple times allowed the researchers to observe change over time. Again, demographic information was included to enhance the generalizability of the results. To establish a more comprehensive and accurate view of changes taking place in the students, the researchers triangulated their own observations and the perceptions of the students with those of the math teacher.

One weakness was the short time frame of the study. If the researchers could have conducted the multiple posttests (motivational questionnaire, mathematics achievement and the teacher's assessment of motivation) over an extended period of time, it would have been possible to see if the impacts of the intervention lasted and for how long.

This strong, well-designed study provides insight into an incremental theory-based intervention. First of all, it shows that such an intervention can develop more incremental views of intelligence in students. Second, it shows that such an impact may positively impact motivation and achievement.

Kunter et al. (2007) conducted two studies to assess the impact of classroom management strategies on seventh and eighth grade students' interest in mathematics and intrinsic need satisfaction in Germany. The two studies will be discussed independently in this section. The first study used a quantitative, cross-sectional, one-shot case study approach to examine the relation of rule clarity and monitoring to interest and intrinsic need satisfaction. The sample consisted of "384 student (53.6% girls) from two academic-track schools in a primarily middle class area of Berlin, Germany" (p. 498).

In the place of a normal math lesson, three questionnaires were administered to students. The intrinsic need satisfaction questionnaire measured three subscales: "autonomy items tap students' sense of self-regulation and choice within class, the competence items tap their sense of mastery and challenge and whether they feel supported in their learning, and the social relatedness items tap their sense of belonging in the class" (p. 498). Students responded to 16 statements on a four point Likert scale. For example, one autonomy item was "In math lessons, I have the feeling that I can make my own decisions" (p. 499). One competence item was "In math lessons, I am considered capable of difficult tasks" (p. 499). A sample social relatedness item was "In math lessons, I experience a sense of belonging" (p. 499).

The classroom management questionnaire measured rule clarity and monitoring. Rule clarity items were designed "to tap students' perceptions of whether classroom rules are clearly stated and implemented" (498). Monitoring items measured "the extent to which the teacher monitors students' actions and is alert to reflect any behavioural problems or learning difficulties" (498). The interest questionnaire elicited students' "feelings about mathematics (liking, looking forward to it) and the perceived importance of the subject" (p. 499). For example, "How much do you look forward to math?" (p. 499). The researchers used a multiple imputation method to estimate missing data. For data analysis, chi-square tests, regression analyses and Sobel's test for mediation effects were used.

The researchers found correlations between rule clarity and math-related interest (r = 0.22, $p < 0.05$), autonomy (r = 0.27, $p < 0.05$) and competence (r = 0.33, $p < 0.05$). The strongest correlation appears to have been between rule clarity and competence. They also found correlations between monitoring and math-related interest (r = 0.32, $p < 0.05$), autonomy (r = 0.38, $p < 0.05$) and competence (r = 0.43, $p < 0.05$). Here, the strongest correlation was between monitoring and competence. Social relatedness was not significantly correlated with either rule clarity (r = 0.03) or monitoring (r = 0.08).

It seems that there are connections between the classroom management elements of rule clarity and monitoring and interest in math, autonomy and competence. With both elements, competence was the most strongly correlated variable. Apparently students' perceptions of personal ability and classroom support were closely associated with the classroom management strategies implemented by the teacher. As mentioned by the researchers, the simple, cross-sectional design did not allow for the drawing of conclusions that one variable caused the development of another. Interestingly, interest in math was more strongly correlated with monitoring (r = 0.32) than rule clarity (r = 0.22).

The researchers strengthened their study by describing the questionnaires in detail. They also included sample questionnaire items to clarify the nature of the subscales. The student population was described in detail as well, except for racial and ethnic information. Turning now to weaknesses, the simple design of the study limits the conclusions that can be drawn from its results. Generalizability is limited by the fact that the researchers only looked at a school in the higher academic track of German schooling. This population was not representative of students in all tracks. The researchers used a more rigorous design in their second study.

Due to the simple nature of this study, little can be determined from its findings. That being said, it does scratch the surface of relationships between classroom management variables and both interest and intrinsic need satisfaction variables. Interest, autonomy and competence are important attitudinal components. This study helps to understand their relation to classroom management.

Kunter et al. (2007) conducted a second study to determine if classroom management variables predicted seventh and eighth grade students' interest in mathematics. The longitudinal study observed a group of students through seventh and eighth grade. The sample consisted of "1900 students (48.5% girls) from 80 classrooms in 80 different schools . . . and all academic tracks" (p. 502). The researchers assessed perceptions of classroom management and interest using the same questionnaires used in the first study. The questionnaires were administered at the end of seventh grade and again at the end of eighth grade. To determine the nature of classroom management in each class, the researchers "aggregated students' ratings of rule clarity and monitoring for each class" (p. 503). In this way the researchers were able to compare and contrast the interest of students in relatively well-managed versus poorly-managed classrooms. Missing data was estimated using a multiple imputation method. For data analysis, the researchers used a multiple regression technique (hierarchical linear models [HLM]).

The researchers found that for individual students "both the level of perceived rule clarity . . . and the level of perceived monitoring . . . seem to exert a small positive effect on interest" (Regression coefficient (R^2): Rule clarity = 0.09(0.03), Monitoring = 0.13(0.03), $p < 0.05$) (p. 504). Upon examining rule clarity and monitoring at the class-level, "no statistically significant effects on interest development were found" (Regression coefficient (R^2): Rule clarity = 0.03(0.03), Monitoring = 0.05(0.04)) (p. 504). The researchers interpreted this lack of significant impacts to mean that "regardless of the overall level of rule clarity or monitoring in classrooms, only a student's personal experience of a transparent and attentive teacher seems to be relevant to interest development" (p. 504).

At the level of individual perceptions, the classroom management elements of rule clarity and monitoring showed small effects on interest. The researchers interpreted this finding to mean that "students who perceive their teachers as setting transparent rules and being attentive to their actions and learning activities tend to develop somewhat higher interest in math than do other students" (p. 504). Perhaps strategically restructuring a classroom management plan to emphasize these elements could result in a change in students' perceptions and thus their interest as well. According to these results, the overall classroom perception of rule clarity and monitoring had no significant impact on interest development. The effect was more visible at the individual level.

This study again had the strengths of well-described questionnaires. It also had the strength of examining variables over time due to the longitudinal design. This also allowed the researchers to use the seventh grade levels as a control for the analysis of eighth grade variables, thus isolating the specific variable that they wanted to assess. The second study also had the strength of examining all academic tracks. This made the study generalizable to students of a broader range of ability.

The researchers did find connections between classroom management and interest. However the connection was relatively weak with only small effect sizes. Therefore, little can be said about these connections. The authors offered some interesting hypotheses, but the study did not have conclusive evidence to support them. The researchers suggested that more research should be done. It could be that connections exist between classroom management and interest and perhaps refined studies in the future will help to clarify this connection.

Summary

While keeping the critiques in mind, Blackwell et al. (2007) suggested that students' theories of intelligence are correlated with motivational variables and achievement. An intervention to teach incremental theory was successful in transmitting understanding of the theory and positively impacting motivational variables and achievement. Kunter et al., (2007) produced less conclusive findings, but suggested that correlations do exist between classroom management and interest, autonomy and competence. All of these studies were conducted in mathematics classes, but it could be that the same practices could work in a science classroom. Along the same lines, the studies were performed with seventh and eighth grade students, but the results could likely be generalizable to upper elementary students.

Technology, Gender and Attitudes

Technology is closely tied to science in both educational and professional settings. As technology continues to advance, it becomes more integrated into our daily lives and the domains of work and school. Many elementary and middle school students are gaining experience with continually advancing science technologies. The following studies examine the relationships between technology, gender and student attitudes. They offer clues about the impacts of technological experiences on attitudes toward science, interest in scientific careers and attitudes about gender competence in technology.

Nadirova and Burger (2008) used a quantitative design to examine the impacts of an enriched science curriculum on elementary students' attitudes toward science. The study was conducted in five control schools and five experimental schools in low-middle to middle class urban neighborhoods in Alberta, Canada. Students in the experimental group experienced three years of science instruction in a new program called Scientists 2010. The program emphasized "integrated learning opportunities at school . . . greater access to computers and the internet . . . museum school weeks . . . e-mentoring of students by volunteers from the community . . . [and] support and encouragement in school, home and community" (p. 34). The researchers administered questionnaires to determine students' attitudes about science after three years of the intervention when students were in grade four. Data was analyzed using explorative factor analysis. The Mann-Whitney test was used to find significant differences.

Nadirova and Burger found several significant differences between project and control groups and between gender groups. For example, "project students scored significantly higher than control students on subscales such as Appreciation of Science and . . . Appreciation of the Science Center" (Appreciation of Science: Project = 4.26, Control = 4.00, $p < 0.05$; Appreciation of Science Center: Project = 4.73, Control = 4.01, $p < 0.01$) (p. 39). This included items such as "Science is one of my favorite subjects" (Project = 4.12, Control = 3.54, $p < 0.05$) and "Visiting the Odyssium [museum] makes me like science more" (Project = 4.62, Control = 4.09, $p < 0.01$) (p. 39). Interestingly, while "there were no statistically significant differences in attitudes toward science between project male and female students (based both on generalized mean attitude subscale scores and on individual item-based mean scores) . . . control girls scored significantly lower than control boys on two items including a confidence item 'I don't do well in science' and a cognitive item 'In science we learn how to make machines we need'" ('I don't . . .': Project females = 3.31, Project males = 4.10; 'In science . . .': Project females = 3.25, Project males = 4.05, $p < 0.01$) (p. 40). Also, "project girls scored higher than control girls on the Appreciation of Science and Practical Application of Science subscales" (Appreciation: Project females = 4.22, Control females = 3.95; Application: Project females = 4.32, Control females = 4.01, $p < 0.05$) (p. 40).

Nadirova and Burger's findings show that students who experienced the Scientists 2010 had more positive attitudes than control students in several areas. The group that experienced technology integration developed more positive attitudes toward science. While the experimental group shows no significant difference in attitudes between male and female students, there were some statistically significant differences in the control group. This finding suggests that the Scientists 2010 program may have contributed to gender equity in the experimental group.

Nadirova and Burger's study has both strengths and weaknesses. The researchers strengthened internal validity by using a control (comparison) group to control for history, testing, instrumentation and regression. Also, the attitudinal questionnaire was field-tested and reworked to improve accuracy. The lack of a pretest is a weakness in the design. A pretest could have established base level attitudes for both groups and controlled for subject mortality. In addition, the researchers did not use random assignment to control for differential selection. Groups could have had different attitudes for reasons other than the new science curriculum. In regards to gender equity, the gender differences found in the control group were only significant for two items. This is not a clear indication of gender inequity, but it does beckon further research.

This study presented a case for the use of technology as a way to engage students and improve their attitudes toward science. Perhaps gender equity was enhanced as a result of the use of technology as well. The use of computers served a dual purpose. It increased the interest of the students who like technology while also preparing them for an increasingly technological world.

Koszalka et al. (2005) conducted a quantitative study of the impact of using web and human resources in suburban, middle school science classrooms on students' interest in science careers. The participating schools "were within a similar range of middle class status" (p. 174). The study used a "one-time cross-sectional observational method" (p. 174) administering a career interest questionnaire to students at the end of an academic year. A total of 619 student surveys were analyzed. A questionnaire was administered to teachers to determine if they used human resources, web resources, a combination of both, or neither. The researchers used two-level hierarchical linear models (HLM) to analyze the data.

The researchers found that students who used web resources had significantly higher career interest than those who did not (average 3.86 points higher on a 36 point scale, $p < 0.002$). Also, students who used human resources had significantly higher science career interest than those who did not (average 2.68 points higher on a 36 point scale, $p < 0.008$). Upon analyzing results by gender, the researchers found that female students who had access to web resources scored significantly higher on science career interest than females who did not have experience with web resources (average 7.1 points higher on a

36 point scale, $p < 0.001$). Female students who had access to human and web resources scored significantly higher on career interest than those who had access to neither (average 16.2 points on a 36 point scale, $p < 0.036$). The researchers also found that "the use of progressively more active and student-centered teaching strategies . . . [was] predictive of student science career interest" (Students who experienced these strategies scored an average 0.76 points higher on a 36 point scale, $p < 0.043$.) (p. 180).

The researchers discovered links between the use of human and web resources and student career interest in science. The findings suggest that the integration of both types of resources had a positive impact on student science career interest. While both types of resources had an impact on science interest, their combined impact was particularly strong, especially with female students. If integrating technology, in the form of web resources, positively impacts female students' interest in science careers, it could work to close the gender gap in interest in science as an educational and professional field.

One strength of this study was the large sample size (619 surveys analyzed) (p. 178). The researchers looked at career interest in a broad range of students. Also, the student questionnaire used in the study had been field tested and shown to have a high degree of reliability (p. 175). One weakness of the study was that the researchers did not assess in detail or describe how human and web resources were used in the classroom. They only looked at whether they were used or not. Another similar weakness was that the authors failed to define "more active and student-centered teaching strategies" (p. 180). The reader is left to consider on his or her own what these strategies might be. This limits the ability to draw specific strategies from the study.

This study piques interest in the integration of both web and human resources in the classroom. Students in classrooms that used web and human resources in science had higher levels of career interest. Increased exposure to information about science careers may have played a part in this change. Students can see opportunities through web resources and role models through human resources. The integration of these resources has the potential to get all students, particularly female students, interested in the field of science and the characteristics of a science-related career.

Beisser (2006) conducted a two-year study of the impact of using Lego®/Logo technologies on attitudes about gender competence and self-efficacy. The study was conducted in a Midwestern elementary school where all 99 students, grade 1-5, participated in daily activities using Lego®/Logo technologies. The students had opportunities to "build machines out of Lego® pieces, connect their machines to a computer and write Logo programs to control the machines" (p. 10). Attitude questionnaires were administered to students in the fall and then in the spring. Students responded to 20 items on a four-point Likert-style scale such as "Boys use computers more often than girls do" and "Boys are better at using technology than girls" (p. 16). Also, the researchers conducted observations of teachers to determine the instructional strategies they used. Data was analyzed with t-tests to find significant pretest and posttest differences for boys and girls and between boys and girls.

Although significant differences between pretest and posttest scores were limited to one item, there were visible trends in changing attitudes. Female students were less inclined to believe "that boys used mechanical skills with computers more than they did (pretest mean = 2.61; posttest mean = 2.03)" (p. 16). Girls disagreed more strongly with the statement that boys are more technologically sophisticated (pretest mean = 1.83;

posttest mean = 1.36)" (p. 16). The researchers pulled out the following strategies from qualitative analysis of teacher observations: "Extended Time . . . Inviting Complex Tasks . . . Purposeful Grouping of Students . . . Longer Processing or Wait Time . . . Students Acting as Experts . . . Probing Questions . . . Authentic Assessment . . . Positive Technology Self-Talk from Teachers . . . Encouraging Construction Behavior for Both Genders . . . Specific Female Encouragement . . . [and] Whole Group Talks on Gender Diversity and/or Individual Differences" (p. 14).

Beisser's findings suggest that the use of technological systems by female students may positively impact their attitudes about gender competence with technology. After a year of technological experience, female students were more confident in the technological competence of their gender. They were less likely to see technology as a masculine entity and more likely to see an equal role in technological fields for females. The strategies identified by Beisser helped female students, and all students, learn effectively from complex, authentic tasks.

Strengths in the study include the mixed methodology and the use of a pretest. Quantitative methods allowed the researcher to observe the impact of technology, while qualitative methods uncovered what strategies may have had an impact on students' attitudes. The pretest established base-level attitudes and in comparison with the posttest allowed the researcher to see changes in attitudes over time. One limitation in the design was the use of only one school. The use of computer technology suggests that this elementary school may be of middle to high socioeconomic status. A single school cannot be representative of the broad range of ethnicity and socioeconomic status found in America's public schools.

While Beisser's findings indicate that the integration of technology may have positive impacts on female students' attitudes, the limitation mentioned above suggests that use of Lego®/Logo technologies may be confined to wealthier schools. Underserved schools may not have the funds to support the use of these technological resources. That being said, the impacts on attitudes, particularly female attitudes, observed as a result of using Lego®/Logo technologies spark interest in technology in general as a means of increasing students interest in science. Creating opportunities for female students to use technology can help to increase their feelings of confidence and competence.

Summary

In the preceding cases, the integration of technology was shown to have a positive impact on student attitudes toward science, career science interest and gender competence beliefs. Nadirova and Burger (2008) found that the integration of technology had a positive impact on student attitudes toward science. Koszalka et al. (2005) discovered that the integration of human and web resources had a positive impact on students' career science interest. Beisser (2006) determined that technology integration positively impacted female students' gender competence beliefs. These studies spark an interest in using technology to engage and excite elementary students. Fostering equal participation in science technology could help to improve female students' competence beliefs and begin to diminish the gender gap in interest in science education and careers.

Active Learning and Projects

The following studies examine attitudes and interest in the context of active or project-based learning. Sometimes active learning takes the form of hands-on experience while at other times it refers to interactive opportunities with fellow students and technology. Some of these studies examine the impact of an intervention while others simply evaluate the base-level attitudes and interest of students. Regardless of the differing individual structures of each study, they all provide interesting insights about the attitudes and interest of students in science in the context of active learning.

Silver and Rushton (2008) examined Year 5 students' attitudes toward science, engineering and technology in England prior to a hands-on science, engineering and technology project. The project was called the Horsham Green Goblin Challenge (HGGC or Goblin) and involved "the construction and subsequent racing of pupil-driven electric cars" (p. 51). The sample consisted of 120 students from four schools in the Horsham town perimeter. At the beginning of the study, the researchers conducted interviews with some school and HGGC personnel to determine a probable range of attitudes. Questionnaires were administered to students before and after experience with the HGGC. Parents and teachers completed questionnaires as well. The article only discussed the result from the pre-Goblin questionnaire.

The questionnaire contained five sections. First, attitudes to school, including science and other subjects, were assessed. Second, attitudes about specific elements of the science and design curriculum were assessed. The third section asked students to define "science", "engineering" and "technology" in their own words. Fourth, students were asked to draw "the sorts of things that scientists and engineers might do" (p. 54). The final section elicited students' attitudes about science and engineering in the broader context of society. The first, second and fifth sections asked students to respond to statements on a five point Likert scale. The researchers coded the results of the open-ended sections (three and four) to allow for quantitative analysis. Chi-square tests were used to determine significant differences.

In sections one and two, students were most enthusiastic (mean scores closest to 1.00) about hands-on activities such as “Designing something” (Mean score = 1.39) and “Making a model that moves” (Mean score = 1.35) (p. 61). Students preferred “Doing the experiment yourself” (Mean score = 1.87) rather than “Watching the teacher do an experiment” (Mean score = 2.66) (p. 61). Writing activities received the least favorable scores in both sections (Section 1 mean score = 3.43; Section 2 mean score = 3.39). In section three, when defining science “over 75% of all descriptions contained two or more positive or investigative words” (p. 56). When defining engineering “over 65% of all descriptions contained one or more repairing word” (p. 56). For descriptions of technology, “over 85% of all descriptions contained two or more positive or creative words” (p. 56). The researchers explained that the students “view science, engineering and technology very differently, seeing science as investigative, engineering as repairing (especially engines) and technology as creative” (p. 60).

Analysis of the children’s drawings from section four showed “58% of drawings showing some form of experimentation and a further 16% indicating ‘thinking’, ‘discovering’, ‘testing’ or ‘inventing’” (p. 57), again showing the students’ view of science as investigative. In their depiction of engineers, 80% of students drew engineers mending automobile engines or other machines. In section five, students “appeared to value the benefits of both science and engineering to society. However, they did not wish to become scientists or engineers” (p. 62). For example, the item “Science has made us better and safer medicines” received a very positive mean score of 1.49 on a five point Likert scale, while “I should like to be a scientist” produced a negative mean score of

4.01.

Sections one and two showed that this sample of Year 5 students preferred to participate in hands-on, active learning in science class. Designing, creating and being given the autonomy to work for oneself were all ideas that appealed greatly to students. These findings suggest that a hands-on, active curriculum could be more effective at getting students to be enthusiastic about science. Sections three and four showed that students have definite, discrete ideas of science, engineering and technology. However, the inaccuracy or incompleteness of some of these ideas may discourage students from exploring areas that they may actually enjoy. The final section showed that indeed students in general do not wish to become scientists or engineers, despite positive views of science in school and society. Perhaps a more accurate view of scientists' and engineers' occupations could result in greater interest in the careers for some students.

The researchers strengthened their study by describing the questionnaire instrument very thoroughly. Also, the questionnaire gave students the opportunity to express their ideas at attitudes through both words and pictures. The researchers used triangulation by combining student views with those of parents and teachers. Unfortunately, a weakness of the design was the failure to provide demographic information for the students. This limits the generalizability of these findings to other populations. Also, no member checks were performed in the context of the students' drawings. Clearly, doing member checks for all of the drawings would have been difficult and time consuming. However, performing checks with a small sample could have strengthened the researchers' findings.

Although the weaknesses of the study perhaps limit the generalizability of its findings, the study has provided many useful insights into students' attitudes and preferences in science. It appears that the students' enjoyed the hands-on and active elements of science the most and found writing to be the least enjoyable part. It could be that an emphasis on active learning and exploration could generate more student enthusiasm. Students generally had positive images of science in society, although this did not coincide with a desire to become scientists. Perhaps part of this gap could be explained by inaccurate or simplistic views of what scientists do. By giving students a more accurate view of the occupations of scientists and engineers, it may be possible to generate more career interest in these fields.

Hugerat, Haiyan, Zadik, Zidani, Zidan and Toren (2004) conducted a study to analyze the impact of a project building a solar village on sixth grade students' interest and opinions of the project in Israel. The quantitative study surveyed the sample population with a questionnaire requiring simple 'agree' or 'disagree' answers. The project involved students, teachers and parents in the construction and operation of a solar energy based model village inside the school. Two of the goals for the solar village project were "to provide the students with knowledge about the sun and solar energy . . . [and] to allow students to participate in promoting and making use of solar energy by developing curiosity for the subject, [and] interest to study it in [the] future" (p. 279). The sample population consisted of "6^{th} graders ($N = 210$), their parents ($N = 172$), and the schoolteachers ($N = 45$)" (p. 279) from three elementary schools. Each group completed a customized questionnaire one year after the project implementation.

The student questionnaire contained scientific, socioeducational and administrative-executive subscales. Students were asked to agree or disagree with statements. The socioeducational items were particularly relevant to attitudes and interest, for example

"Carrying out such projects made me interested and strengthened my creative ability" and "There is a relation between the things I learned in the project and the daily life" (p. 280). One of the scales on the teachers' questionnaire allowed teachers to judge the educational value of the project and evaluate their students' interest in it. Parents had a similar opportunity to evaluate educational value and student interest on their questionnaire. Data analysis was undertaken comparing descriptive statistics.

Students were very positive about the solar village project. Almost all (88%) students agreed with the statement "Carrying out such projects made me interested and strengthened my creative ability" (p. 280). Also, 90.5% of students saw "a relation between the things I learned in the project and the daily life" (p. 280). Overwhelmingly (91.4%), students thought "the general benefit of the project was positive" (p. 280).

Teachers responded favorably to the project as well. A vast majority of teachers (88.9%) believed that "students' response and interest in the project was excellent" (p. 280). Almost all teachers (95.6%) agreed that "this kind of project strengthens the skills and promotes creative abilities among students" (p. 280). All teachers thought the project was beneficial to students. Parents also had positive opinions of the project. Many (88.4%) agreed that they had seen their child "follow the project with lots of interest (p. 281). Also, 93% of parents saw the "project as a positive step toward the promotion of thinking and creativity among children" (p. 281).

The student responses pointed to the project as a potential source of promoting student interest. Importantly the statement referred to interest in the project rather than a general interest in science. The project seems to be relevant to most students as evidenced by the connection between the project and everyday life. It is clear that the project was very popular with students in general. The solar village project was strongly supported by teachers and parents. Both groups saw a positive impact on students' interest and creativity. It is important to assess the strengths and weaknesses of this study to determine the reliability and generalizability of its findings.

The study contained several strengths. First, the questionnaires were customized for each particular group (students, teachers, parents). This helped to assure that the statements would be relevant to the party being questioned. Second, the researchers provided the questionnaires and response data in their entirety. In this way, they showed exactly what was asked and how those questioned responded. Finally, the researchers used triangulation by combining student, teacher and parent attitudes. The resulting combination of data was more comprehensive, giving a fuller picture of the school community's attitudes and opinions of the project.

The weaknesses and limitations of the study are relevant to assessing the reliability of its findings. One major weakness is the lack of a pretest. If students' interest in solar energy and a potential project could have been assessed before the implementation of the project, the impact of the project could have been better isolated. Another weakness is the use of a binary response option. Participants had to either totally agree or totally disagree. A five point Likert scale, as used in many other studies, would have provided more accurate representations of attitudes and opinions of the project.

It certainly appeared that students, teachers and parents had favorable opinions of the solar village project. These opinions could have appeared more favorable than they really were due to the binary nature of the questionnaires. Keeping that in mind, the responses from all groups indicated that the project produced student interest. This interest primarily referred to interest in the project rather than a general interest in science. An item assessing general interest in science would have been a valuable addition to the questionnaire. That being said, it could be that a project like the solar village could have a positive impact on students' interest and perceptions of their creative ability. It also has the potential to create stronger home and school connections making science learning relevant to the everyday lives of students.

Allen and Fraser (2007) used a mixed methodology to examine the correlations between grade four and five students' and parents' perceptions of the science classroom and attitudes and achievement. The correlational case study took place in an urban school district in Miami, Florida. One of the researchers was a teacher of two of the 22 classes, at one of the three schools in the study. The sample consisted of 520 students, aged nine to eleven and 120 matched parents. Many of the students were of Caribbean, Central American or South American descent.

Students' and parents' perceptions of the classroom environment were measured with a modified version of the What Is Happening In this Class? questionnaire. The questionnaire contained four forms. Two forms "were used to measure students' and parents' preferred classroom environment, while the other two forms measure students' and parents' perceptions of the actual classroom environment" (p. 70). The questionnaire assessed "Student Cohesiveness, Teacher Support, Involvement, Task Orientation, Equity and Investigation" (p. 70). To assess student attitudes, the 120 students matched with cooperating parents completed the Test of Science-Related Attitudes. Achievement was measured using a mandatory, standardized science test and final grades in science. The researchers also conducted interviews with ten students and their parents. The researchers used the following types of analyses: factor, item, simple correlation, multiple regression, ANOVA and MANOVA.

The focus here will be on the correlations between students' perceptions, attitudes and achievement. Understandably, a significant correlation (r = 0.23, $p < 0.01$) existed between students' perceived Investigation (as measured by the WIHIC questionnaire) and their Attitude to Science Inquiry. The scales of Involvement and Task Orientation were significantly correlated with Enjoyment of Science Lessons (r = 0.24 and r = 0.33, respectively, both $p < 0.01$). No significant correlations were found between students' perceptions of the classroom environment and their achievement measures. Through the interviews, the researchers found that generally, "students were satisfied with their science classroom learning environments" (p. 80).

The correlations observed suggest that relationships exist between students' perceptions and their attitudes. Students who perceived more investigation in science class had more positive attitudes to science inquiry. This finding suggests that students who participate in investigative activities may become more interested in the activities and the inquiry process. Though this trend is significant, the effect size is relatively small (r = .23). Involvement was significantly correlated with enjoyment of science lessons. Students who felt more involved in the classroom enjoyed science more. If curriculum is structured to actively involve all students, it could be that it will be more effective in improving students' attitudes toward science. Again, the trend is significant, but the effect size is relatively small (r = .24). The strongest correlation observed was between task orientation and enjoyment of science lessons (r = 0.33). Unfortunately, task orientation is not defined by the authors, but this variable has been interpreted as measuring the extent to which students know what to do and do it. It seems that students who are aware of what to do and complete tasks tend to enjoy science more.

The researchers strengthened their study by combining quantitative measures of questionnaires and tests with qualitative interviews. They also used triangulation combining their views with those of students and their parents. For the sample population, demographic information was well-described. An unfortunate weakness of the design was the failure of the researchers to define the six dimensions of the WIHIC questionnaire. This made it difficult to interpret the quantitative findings. Also, more interviews and a more substantial discussion of the results would have helped strengthen the qualitative elements of the study.

This study provides good evidence that students' perceptions of their science classrooms are related to attitudes. Though the effect sizes of these correlations were often small, the correlations were significant. These significant correlations surely merit further exploration. It could be that active, inquiry based learning could change students' perceptions of science inquiry and this change could coincide with a change in attitudes. Changing students' perceptions could be a possible pathway to improving students' attitudes in science. It seems that getting students involved, potentially through active, inquiry-based learning has the potential to improve their enjoyment of science. In this study, student perceptions did not appear to be significantly correlated with achievement.

Simons et al. (2004) conducted a mixed methodology case study to evaluate the impact of a problem-based learning (PBL) unit on sixth grade students' learning and attitudes and determine strategies employed by the teacher during the unit. The sample consisted of 19 students (12 female, seven male) and their teacher "in an enrichment course entitled ‘Global Connections’” (p. 215). The students “ranged in ability from high-achieving to special education” (p. 216). The seventh-year teacher had never used PBL before. *Up, Up, & Away!*, an interdisciplinary unit, involved planning a nonstop circumnavigation of the globe in a hot air balloon and was taught to students in six 50 minute class sessions. The computer-based unit was undertaken by students in self-selected groups of two or three. Verbal and written feedback was given to the students by the teacher on a regular basis. Interviews with the teacher, as well as class observations, were conducted to identify strategies used by the teacher.

To assess attitudes, the students were given an attitudinal survey. The survey consisted of seven Likert scaled items and three open-ended items. The scaled items “asked about such things as the ease of using the student interface, student effort in completing the unit, ease of finding information and feelings toward *Up, Up, & Away!* [italics author]” (p. 218) The open ended items asked students “what they liked best about the unit, what would have helped them do a better job of completing the unit, and what they felt should be changed about the unit” (p. 218). Five students were randomly selected to be interviewed. Student achievement was measured by student projects and the posttest supplied with the unit materials. The projects were independently rated with three categories “Balloon Design, Supply List, and Travel Plan” (p. 220). The researchers used descriptive statistics to analyze the data.

The researchers found that “most students would enjoy completing a project like *Up, Up, & Away!* [italics author] again” (Mean score = 1.8, on a scale from 1-4 with 1 representing strongly agree) (p. 226). Some students did not feel that they had enough time to complete the project (Mean score = 2.6). The open-ended responses showed several trends. Some students “wanted to be given more information . . . [and] would have preferred to make an actual balloon model rather than just a drawing of their balloons” (p. 226). Despite the interactive nature of the project, these students desired more hands-on activities. Also, “several expressed they liked the sense of ‘being in control,’ and doing something ‘new and different’” (p. 226). These attributes could be described as autonomy and novelty respectively. Most of the students “stated they needed more time to research and complete the project” (p. 226). The teacher also often expressed frustration to the researchers about not having enough time to complete the activities.

Through observations and interviews the researchers gleaned the strategies of “determined and extemporaneous questioning . . . substantive reliance on peer-to-peer support . . . individual and group feedback . . . [and] structured management of the environment” (p. 227-228). Questioning allowed the teacher to guide students without giving them answers. Setting up peer support connections helped expand students’ resources by using each other to get information. Also, the approach freed up time for the teacher, allowing her to attend to the most significant needs in the classroom at any given time. The folder-based feedback system both informed the teacher of student progress and informed the students of expectations. Structured management of the environment was achieved by “establishing clear, attainable goals and communicating daily expectations” (p. 228).

Students perceived many benefits in the PBL unit. The unit offered novel activities and information as well as opportunities for student autonomy. The teacher encouraged this autonomy through the establishment of peer-to-peer support systems. Students interviewed mentioned their autonomy as a favorable attribute of the project. The positive aspects were enough to convince most students to want to do a similar project in the future. It appears that PBL has the potential to benefit students and increase their enthusiasm for projects such as *Up, Up, & Away!*.

One obstacle to an effective PBL project appears to be a lack of time. Both teachers and students complained of a lack of time to complete the project. The researchers do admit that PBL takes more time than standard instruction. It could be that if a PBL project is not given this extra time, it will be less effective in teaching students about the subject at hand. This time constraint could have a negative impact on students' attitudes toward science and PBL.

The researchers strengthened their study through triangulation. A combination of student attitudes, teacher attitudes and researcher observations gave a more complex picture of the educational environment. A type of member checks were performed with teachers through debriefing sessions. Through this approach, the researchers were able to compare their observations with the teacher's perceptions. The researchers strengthened the dependability of the study by supporting the strategies and observations produced with previous research.

Weaknesses were present in the study as well. The participants of the study were not well-described demographically. No race, ethnicity, class or location information was given for the student population. Also, the sample size in the study was very small. The observation and assessment of multiple classes, perhaps at different schools, would generate a more accurate picture of the average experience with a PBL project. These additions would strengthen transferability as well.

The implementation of a PBL project resulted in positive perceptions for many students involved. Admittedly the sample size was small, but it could be that these benefits could be perceived by other students undertaking a PBL project. Strategies of questioning and peer-to-peer support could provide opportunities for student autonomy. These strategies could be used with or without problem-based learning. Providing enough time for students to satisfactorily complete activities seems to be important for the morale of students and teachers. It could be that time could have an impact on student learning as well.

Summary

These studies have examined the attitudes and interest of students in relation to active learning and project-based learning in science. The findings suggest that active and project-based learning have the potential to engage the enthusiasm of students. Silver and Rushton (2008) pointed to students' desire to engage in hands-on, active exercises. Hugerat et al. (2004) found that the popular solar village project was perceived by students, teachers and parents alike to encourage student interest. Allen and Fraser (2007) showed a significant correlation that students who perceived more investigation in science class had more positive attitudes to science inquiry. Simons et al. (2004) showed students who experienced problem-based learning generally expressed interest in similar future activities. Also, some spoke of autonomy as a benefit of PBL. The studies provide an illuminating introduction to student attitudes in science in an active learning context. Further study will help to maximize the positive attitudinal impacts of active learning practices.

Cooperative Learning and Attitudes

In addition to being a place of learning, the public school classroom is a place of social interaction. The following studies examined the potential benefits of social interaction and cooperative learning on the attitudes, perceptions and interests of their participants. While cooperative learning was not the sole focus of any of these studies, it was an important component of each one. Gläser-Zikuda et al. (2005) examined the impacts of a student-centered learning approach that utilized cooperative learning on students' emotions and achievement. Chang and Muñoz (2006) evaluated the effects of a character education program that used cooperative activities on students' attitudes about school and their teachers. Fields (2009) investigated students' perceived benefits of a summer astronomy camp, including the benefits of social interaction. The sample populations of these studies ranged from elementary to secondary school. All of these studies provide useful insight into the world of cooperative leaning and its potential impacts on student attitudes.

Gläser-Zikuda et al. (2005) studied the impacts of the ECOLE (Emotional and Cognitive Aspects of Learning) approach on eighth and ninth grade students' emotions and achievement in southwestern Germany. The researchers utilized a quasi-experimental, nonequivalent control group design. The ECOLE approach emphasized student-centered instruction, active learning, transparency, feedback, cooperative activities and authentic tasks. Cooperative and play-like activities were used "to enhance interest, supportive and pleasurable ways of learning that increase well-being and reduce anxiety" (p. 485).

The first phase of the treatment focused on "highly student-centered instruction, no grades (but individual feedback), tolerance of mistakes, and no performance pressure" (p. 485). The second phase of the treatment became "more teacher-centered focusing on the correction of mistakes, and on students' learning success assessed through different types of applicational exercises" (p. 485). To negate the impact of teachers' personalities "five biology teachers and seven physics teachers taught their regular classes (control groups), and afterwards applied the ECOLE approach in a different class (treatment groups)" (p. 486). This was not possible in German instruction, so six teachers taught control groups and nine taught treatment groups. The study took place around a period of 12-18 lessons.

For the pretest measure of achievement, the researchers used previous grades in the subject (or a comparable subject) and domain specific pretests. For the first posttest, a regular graded class test was used. A follow-up test (second posttest) was also given. Psychometric (emotional) data was collected before and after the treatment. Students were given a chance to grade aspects of instruction such as "instructional material" and "quality of teachers' instruction" (p. 487). The instrument used to collect emotional data was poorly described in the study. The researchers used the General Linear Model Procedure to calculate a multivariate analysis of covariance.

The only significant increase in positive emotions was a small increase in interest in German in the control group (no mean scores given, Effect size = 0.02, $p < 0.05$). No other significant emotional changes occurred in German, physics or biology. The researchers suggested that "a teaching unit including 12-18 lessons of instruction might have been too short to influence emotions" (p. 492). They also proposed that "new ways of learning may have created insecurity in the students and therefore partly led to the opposite of the expected effect" (p. 492). Significantly higher scores in achievement were observed in the control group compared to the experimental group in all subjects on the first posttest (no mean scores given, Effect sizes: low (< 0.06), moderate (0.06-0.13), high (≥0.14); Biology = 0.03, $p < 0.05$; German = 0.12, $p < 0.001$; Physics = 0.12, $p < 0.001$). These differences were maintained through the time of the second posttest (no mean scores given, Effect sizes: Biology = 0.08; German = 0.27; Physics = 0.14, all $p < 0.001$).

The findings of this study suggest that the ECOLE approach, including elements of student-centered instruction and cooperative learning, can have a positive impact on achievement when compared with traditional, teacher-centered instruction. The approach seemed to have a positive impact across subjects. As for emotional impacts, only a small change was observed in interest in German. It appears that the ECOLE approach did not have any other significant impacts on emotions in the timeframe of the study. It could be that a longer treatment period could have yielded different results. Further study would be needed to explore this possibility. While these inferences are given merit by the strengths of the research design and method, the weaknesses limit their validity.

By using the same teachers for control and treatment groups, when possible, the researcher controlled for the impacts of personality and other teacher-specific differences. The use of a control group helped to negate any historical differences in the control and treatment groups as well as maturational changes that may have impacted emotions or achievement. The use of multiple types of pretest and posttest measures strengthened the validity of the study. One point of weakness was the researchers' failure to adequately describe the instrument used to collect emotional data. Because this instrument was not well described, it cannot be assumed to be valid. Unfortunately, the student demographics were also poorly described limiting the ability to generalize these results to other groups of students.

At face value, the ECOLE approach appeared to have positive impacts on student achievement in science. It also appears to have had no significant impact on emotions in the amount of time the researchers observed. Due to the limitations of the study, the validity of the emotional tests cannot be determined. Another important factor to consider is that this study was not conducted with elementary students. The subjects were between 13 and 15 years old. It cannot be assumed that the results of this study would simply transfer to younger students. Nevertheless, the study provided an interesting view of a student-centered teaching approach that provides cooperative learning opportunities to students.

Chang and Muñoz (2006) evaluated the impact of a character education program on third, fourth and fifth grade students' attitudes about school and their teachers. They examined both student and teacher attitudes with a "quasi-experimental evaluation design (Rossi et al., 1999) with eight treatment schools and eight control schools" (p. 39). The focus here will be on the sections concerning student attitudes. The researchers selected treatment schools that had a "significant achievement gap between minority and non-minority students on the state-mandated assignment" (p. 38). To create similar control and treatment groups, "a one-to-one match was run at the school level yielding a comparison group that was matched with the treatment group on: percent poverty, percent Exceptional Child Education (special education), percent mobility, percent single parent household, and previous achievement test scores" (p. 39). The large treatment group and control group populations were 1,883 and 2,025, respectively. The sample population was “35% African-American, 58% White and 8% Other. A little over half of the students (54%) are from single-parent households and 61% are from low-income backgrounds” (p. 38).

The research administered a questionnaire to evaluate students’ attitudes about school and teachers. It consisted of Likert-type items including subscales of “*student autonomy* . . . *classroom supportiveness* . . . *liking of school* . . . *trust and respect for teachers* . . . [and] *concern for others* [italics author]” (p. 42). The questionnaire was administered in the fourth year of the implementation of the Child Development Project (CDP). The CDP “aimed to help teachers to foster children’s higher order learning and intrinsic motivation to learn and to increase students consideration of and concern for others’ welfare” (p. 36). The program is particularly relevant to this section because a major component was “cooperative activities which encouraged students working together to solve problems and build relationships and create caring classroom communities” (p. 38). The researchers used the multivariate analysis of covariance (MANCOVA) and follow-up univariate tests to analyze the attitudinal data.

The student questionnaire revealed that the treatment group had a significantly higher score on the student autonomy and influence in the classroom scale than the control group (Treatment = 2.45, Control = 2.26, $p < 0.001$). Also, the treatment group showed a significantly higher score for classroom supportiveness than the control group (Treatment = 2.99, Control = 2.92, $p < 0.01$). With respect to age differences, the researchers found that older children had significantly lower scores than their younger counterparts on all attitudinal subscales (no mean values or level of significance given). A graph of mean autonomy and influence scores for ages eight through 11 shows “consistently stable ratings of autonomy and influence in the classroom by younger and older children in the treatment programs, while older children in the control programs declined in their ratings of autonomy and influence when compared to younger children" (p. 43-44).

It appears that the Child Development Project had a positive impact on students' attitudes of student autonomy and influence and perceptions of classroom supportiveness. If these results are valid, the CDP may have given students a greater sense of control over their learning. Perhaps the cooperative activities helped to give students an improved sense of classroom supportiveness. Increased interaction between students could have improved relations in the treatment group. The CDP seems to have lessened the downward trend of attitudes in elementary students with age. The control group showed a sharper decline in attitudes with age. Importantly, the study was not longitudinal, it simply compared students from third, fourth and fifth grades. Before these inferences are given credence, it is useful to examine the strengths and weaknesses of this study.

The researchers strengthened their study with a matched control group. Matching the schools on demographic variables yielded more similar treatment and control groups. Also, the researchers gave detailed demographic information about their sample population and explained the reason for selecting treatment schools (an achievement gap between minority and non-minority students). Unfortunately, the study did not use a pretest. The design only allowed for one examination of student attitudes in each group. It is impossible to determine if student attitudes were similar or different prior to the implementation of the program without a pretest. Although, the schools were matched on many variables, they still could have begun with different attitudes.

It could be that the Child Development Project had a positive impact on students' feelings of autonomy and classroom supportiveness. On the other hand, the lack of a control group poses a threat to validity. The observed impacts may have been influenced by fundamental differences found in the treatment and control groups. Without a pretest, it is difficult to quantify the impact of the CDP. It is possible that the CDP was responsible for the attitudinal changes observed including the lessened impact of age on attitudes. The program certainly deserves further exploration. An exploration of other studies that examined treatments focused on cooperative activities might lend more dependability to this study.

Fields (2009) conducted a qualitative case study of high school students' perceived benefits of a summer astronomy camp. The researcher fulfilled the role of participant observer by both serving as a staff member at the camp and observing and interviewing students and staff. The 33 participants (16 female, 17 male) were accepted into the camp on a first-come, first-served basis. Data on ethnicity or race was not collected. Campers, staff members and the director of the camp were interviewed. The researcher explained that the camp staff "tried to instill confidence in the campers by drawing the kids out or by using the science that kids were doing to help them develop a sense of achievement" (p. 166). The director of the camp wanted campers "to experience the whole process of science . . . see that science is fun . . . [and] make friends" (p. 156). Activities performed in the camp included night observations, lectures on astronomy, debates and research projects. The following description will focus on the ten interviews performed with campers.

In order to collect an accurate sampling of the group, the researcher selected ten students "representative of the Camp in terms of age, gender, and previous astronomy camp experience" (p. 158). Questions posed to the campers fell under three categories: "affective aspects (confidence, community, a memorable story), science knowledge, and future goals (careers and higher education)" (p. 159). Interview data was analyzed using a "two-step open coding process" (p. 159). First, interviews were coded with themes the researcher developed. This first coding also allowed for the development of additional subthemes from camper and staff responses. The second coding involved both original and new subthemes which "were considered significant if all or most (≥80%) of the campers or staff said something regarding them" (p. 160).

The researcher identified several themes relevant to the research question. First, most of the campers spoke of the benefit of peer relationships. Fields suggested that "knowledge that others of their age were also interested in science validated the campers' prior and continued identification with science and may have been important for the persistence some youth expressed in terms of future hopes of pursuing science" (p. 161). Second, all students interviewed spoke about feelings of personal autonomy. For example, "all youth talked about the agency to choose their own research topics as empowering" (p. 162). Finally, in regards to interaction between students and staff, the students described "informal and egalitarian relationships [that] helped them approach staff for questions and make themselves understood" (p. 162). One camper explained that because of these egalitarian relationships "'no one's afraid to ask questions, or make suggestions, or things like that'" (p. 162).

This study highlighted some of the potential benefits of a summer astronomy camp on students' perceptions and attitudes. Most campers perceived improved peer relationships to be a benefit of the camp. The researcher suggested that these strengthened relationships and peer interaction may help validate students' interest, including career interest, in science. It appeared that a camp that allows students to have choice in their pursuits may give students a greater sense of autonomy and control over their learning. The more informal environment of a summer camp could have more opportunity for this type of freedom than a public school classroom. The informal atmosphere could also enhance student-staff relations and students' willingness to question and contribute.

The researcher strengthened the qualitative study through the use of triangulation. Perceptions of campers, staff and the director were collected for an accurate view of the perceptions of all parties involved. Another strength was the use of member checks. Transcripts of interviews were sent to interviewees for verification and no subtractions were requested. In this way, the researcher took care to make sure that she was accurately representing the perceptions of those interviewed. The study's lack of race and ethnicity data limit the transferability of the findings.

The purpose of this study was not to establish quantitative relationships. It was simply an evaluation of trends in the experience of science campers. Treated as such, conclusions should not be drawn from the findings. Instead, the findings serve as fertile ground for further exploration and experimentation. It appears that cooperative activities hold a host of potential benefits for the attitudes of their participants including validating personal interest in science. Importantly, this study was performed with high school students, not elementary students. The nature of a camp designed for elementary students may differ from that of high school students. Although the opportunities at camps for elementary students may differ, surely opportunities for social interaction can be included and could have positive impacts on students' perceptions, attitudes and interest.

Summary

While these studies may lack strong correlations and solid quantitative evidence, they do provide an interesting view of the potential impacts of programs using cooperative learning. Gläser-Zikuda et al. (2005) found that the ECOLE approach did not appear to have an impact on emotions, at least in the short-term. Chang and Muñoz (2006) discovered that the CDP appeared to enhance students' perceptions of autonomy and classroom supportiveness. Fields (2009) found that an astronomy camp offered opportunities for autonomy, peer interactions and validation of interest.

Extracurricular Science Opportunities

This section contains studies about extracurricular science experiences. "Extracurricular" means that these experiences occur outside of the normal curriculum. Falk and Balling (1982) compared the impacts of an off-site field trip with an on-site (at school) outdoor activity on elementary school students' attitudes and behavior. Jarvis and Pell (2005) examined the impacts of a field trip to a space center on students' attitudes. Dimopoulos, Paraskevopoulos and Pantis (2008) evaluated the impacts of an environmental education program given by a guest teacher. All of the studies examined the attitudinal impacts of these programs.

Falk and Balling (1982) examined the impact of a field trip on students' attitudes, behavior and learning in two suburban public schools. The schools were "in the mid-Atlantic area of the United States . . . [and] classes were predominantly white from middle and lower-middle socioeconomic backgrounds" (p. 23). From each school, two third grade classes and two fifth grade classes participated. For each grade, one group served as the treatment group and the other served as the control group in a nonequivalent control group design. All students took a pretest four weeks before the field trip. The treatment and control groups participated in the same activity. The treatment group completed the activity on a field trip at a nature center, while the control group completed the activity in a wooded area near the school. Students completed a posttest one day after the activity and one month later. The attitudinal data which was collected through questions on the pretest and posttests will be focused on here. The researchers analyzed the data using chi-square tests.

The pretest showed that 82% of the students preferred to undertake an activity involving trees on a field trip to a nature center, rather than just outside their school. The researchers also found that “on the first posttest, the fifth graders were significantly more certain than the third grade students that they would remember what they had learned for a month or more” (Grade 5 = 86.7%, Grade 3 = 65.6%, $p < .025$) (p. 26). By the second posttest, the levels of certainty were about equal between grades (Grade 5 = 81.5%, Grade 3 = 86.8%). In a question regarding recognition of the site of the activity, “the number of students who were sure that they could easily recognize the nature center site was significantly lower than the number of those who felt they could recognize the location near their schools” (Nature center = 34.7%, School = 49.5%, $p < 0.001$) (p. 26). The researchers found that “in general, all students expressed a positive attitude towards field trips and outdoor experiences . . . [and] overwhelmingly indicated that the field trip activity in which they participated was ‘really great’” (p. 27).

The pretest showed the popularity of field trip experiences away from the school. It appears that the third graders were somewhat less confident than fifth graders about remembering the location shortly after the trip. It could be an impact of age that with maturity comes more confidence about memory and new places. Regardless of the cause, the gap disappeared by the second posttest. Also, students seemed more confident about remembering locations that were closer to the school. Possibly the newness of the nature center could make it more difficult to remember. Remembering the location is important for students, particularly visual learners, who link the knowledge that they gained on the field trip with the environment itself. Ideally, their memories of the location will be linked with the ideas that they learned there. Both groups appeared to have enjoyed the activity and feel positively about it. These are merely inferences and possibilities. The strengths and weaknesses of the study must be examined before drawing any ideas from the study.

There were several strengths in the research design. The researchers used a pretest to establish base attitudinal levels as well as two posttests to measure attitudes about recall and the value of the experience right after the experience and two months later. The use of a control group helped to offset any changes that came about as a result of factors other than field trip location. Multiple grades were examined to look for possible differences in attitude between third and fifth grade. The location and demographics of the school were well described by the researchers. One weakness of the design is that the pretest and posttests were not equivalent. The attitudinal data could not be compared as a result. Also, a limitation of the study was that only two attitudinal questions were present on the pretest and only three on the posttests. The examination of attitudes was not very thorough, as it was only one of the domains that the researchers studied (along with behavior and learning).

While this study presented some interesting ideas about attitudes and field trips, attitudes is not its primary focus. As a result, the ideas that can be drawn from it are limited. Field trips, at school or off-site, appear to be popular with students, but whether or not they can positively impact students' attitudes is not shown by this study. Also, it could be that attitudinal effects of field trips could differ depending on age. This is an important idea to consider when planning field trips for different grade levels.

Jarvis and Pell (2005) used a mixed methodology to examine the impact of a field trip to the UK National Space Centre on 10 and 11 year old students' attitudes. The sample included students from ten classes at four schools (one inner city/mixed ethnicity, one urban/mostly white, one suburban/mixed ethnicity, one suburban/mostly Indian/Pakistani ethnicity). An attitudinal pretest was given to students one month before their visit to the Space Centre. Attitudinal posttests were administered three times: about one week, two months and four to five months after the visit. Interviews were conducted with students and their teachers about a week after the visit and four to five months later. For interviews, the researchers used "a grounded theory approach in which children at the extreme ranges of expected significant categories were selected" (p. 57). The researchers observed students, teachers and helpers during the field trips.

The attitude questionnaire contained the following attitudinal scales: "[The] *Science enthusiasm* scale focuses on feelings about engaging in science at school and at home . . . *Science in a social context* scale asks children about their views on the uses of science to improve the human condition . . . *Space interest* scale probes children's views about the value of space exploration . . . *Planning and teamwork* evaluates how much the children value planning with peers . . . *Working confidence* scale gives a measure of feelings about taking a leadership role and responsibility for decisions . . . *Anxiety* scale indicates how far children worry about finding schoolwork hard, being wrong, and/or being alone in school [italics author]" (p. 56-57). The science enthusiasm scale is the most relevant to this paper.

All schools visited the main exhibitions in the Space Centre. Three of the schools also visited the Challenger Centre. Educational support was not provided by museum staff in the main exhibitions. Students were guided by "teachers, classroom assistants, bilingual support teachers, and parents" (p. 59). Specificity of tasks and instructions varied greatly between classes. In the Challenger Centre, museum staff led activities "acting as 'flight directors'" (p. 60). Classes were divided into two groups and experienced a simulation in which one group was in a space shuttle and the other group was at a control center. The groups switched midway through in order to experience both areas. The researchers used MANOVA and t-tests to analyze the data.

The researchers found "no evidence of the visit having a statistically significant effect on children's enthusiasm for science based on the scores for all children" (Pretest = 15.42, Posttest 1 = 15.62) (p. 63). Female students' *science enthusiasm* scores were significantly lower than those of male students and remained so throughout all three posttests (Mean scores (female/male): Pretest = 14.40/16.36, Posttest 1 = 14.60/16.55, Posttest 2 = 14.29/16.56, Posttest 3 = 13.90/15.97) ($p < 0.01$). For female students, *space interest* significantly increased immediately after the visit ($p < 0.01$), but waned to approximately the pretest level by last posttest five months later (Pretest = 18.28, Posttest 1 = 19.13, Posttest 2 = 18.72, Posttest 3 = 18.08). Though not statistically significant, a small increase in male students' mean scores for *science in a social context* (0.25 of a standard deviation) was found after the first posttest and remained for the five month duration (Pretest = 20.23, Posttest 1 = 20.82, Posttest 2 = 20.93, Posttest 3 = 20.81).

From the interviews conducted, "the children overwhelmingly spoke positively about the simulation. About 90% responded very positively to the idea of repeating a visit to the Challenger simulation" (p. 62). Unfortunately, "children's interviews indicated that the post-school experience might have a dampening effect on their enthusiasm (p. 63). The researchers recommended a list of procedures for making field trips effective focusing on explaining the purpose and expectations for the visit to students before the trip.

Although there were no significant impacts on *science enthusiasm* and *science in a social context*, a small change in mean scores for the latter suggests that the trip could have had a small impact on student attitudes. This study suggests that a field trip, such as the one to the Space Centre, can have an impact on female students' interest in space. It appears however, that this impact is not necessarily self-sustaining and may require support in the classroom to maintain it. The interviews conducted suggest that post-school experiences may fail to support gains in science enthusiasm related to field trips. Perhaps the recommendations given by the author could help teachers link classroom and field trip experiences more closely and make field trips more efficient and effective.

The researchers strengthened their study by using qualitative analysis to uncover reasons for quantitative results. Listing school demographics (racial composition and inner-city, urban, suburban) and choosing schools with a range of these demographics strengthened the ability to generalize the findings. One weakness in the researchers' approach to interviewing was that it ignored students in the middle on attitudes. Surely these students have legitimate insights concerning field trips, in-school experiences and personal attitudes towards science.

Although this study did not find many significant impacts on students' attitudes, it did find some, suggesting that impacts were possible. So, while the question of whether field trips can have an impact on student attitudes seems to merit an affirmative answer, the questions of what specific impacts can be achieved and how the can they be achieved still remain. In the recommendations, the authors begin to suggest ideas for more effective and efficient field trips, though the study does not systematically analyze the potential effects of any of these recommendations. This list obtained through the valid qualitative and quantitative methods employed in this study, certainly provides fruitful ground for future study.

Dimopoulos et al. (2008) conducted a quantitative study of the impacts of an environmental education unit about sea turtle conservation on students' attitudes and knowledge on the island of Zakynthos, Greece. The research followed a quasi-experimental, nonequivalent control group design. Students ranged from 11-13 years old. The experimental group, 16 classes from eight schools (178 students total), experienced an environmental education program. The control group, 14 classes from seven different schools (154 students total), received no environmental education from the researchers. Both groups completed a pretest questionnaire "on average 18 days before" (p. 54) the program was given to the experimental group. The posttest was given to all students approximately nine weeks after the treatment on average, in order to examine the lasting impacts of the treatment.

The 32 item questionnaire measured four subscales: *Knowledge*, *Understanding and Concern*, *Locus of Control* and *Verbal Commitment*. *Knowledge* questions contained multiple choice items such as "Where do sea turtles nest?" (p. 49). *Understanding and*

Concern questions such as “Do you believe it is bad for us humans if sea turles become extinct?” (p. 50) used five-point Likert-type response scales. Similarly, *Locus of Control* questions such as “Do you think you have a role in protecting sea turtles?” (p. 50) and *Verbal Commitment* questions such as “Would you wake up at 6 o’clock in the morning to protect the sea turtle nests? (p. 50) used Likert-type response scales.

Activities for the conservation education module were completed primarily in class (with two out of fifteen completed at home), both in groups and individually. These activities included slide presentations, interpreting photographs, drawing, letter writing, role-playing, debate and a family interview. The activities were led by the primary author of the article (Dimopoulos). For data analysis, the researchers used the Wilcoxon Signed Ranks test and the Mann-Whitney U test.

The pretest revealed that no statistically significant differences existed between the experimental and control groups on any of the four subscales (Mean scores (Experimental/Control/*p*): Knowledge = 33.28/29.55/0.244, Understanding and concern = 79.60/80.47/0.394, Locus of Control = 77.91/77.08/0.901, Verbal Commitment = 85.29/84.31/0.371). After the treatment, “the class mean scores for knowledge . . . were significantly higher in the experimental group than in the control group” (Experimental = 33.28, Control = 29.55, $p < 0.0005$) (p. 55). The researchers found no significant changes in attitudes in either group. However, within the experimental group, “significant and positive correlations emerged between the variable of knowledge and that of understanding and concern ($r = .638$, $p = .008$) . . . and between the variable of understanding and concern and that of locus of control ($r = .540$ and $p = .031$)” (p. 55-56).

The researchers did not discover any significant changes in attitudes after the implementation of the environmental education program. The researchers suggest that "this finding may be attributable to the fact that pretest attitude scores were already high" (p. 56). This could be true, but it does not substantially support the use of environmental education programs to change attitudes. Interestingly, the researchers found correlations between the variables of knowledge and understanding and concern. As students gained knowledge, their understanding and concern increased as well. Importantly, this is not a causal relationship, only a correlation.

One major strength of the study was the use of a control group to control for knowledge and attitudinal changes due to factors other than the treatment (school, media, experiences at home). The use of a pretest established base-levels of attitudes and knowledge within the experimental and control groups. Another strength of the study was the researchers' thorough description of the treatment activities. Unfortunately, these strengths are undermined by weaknesses of overgeneralizations. The researchers claimed that "The conservation education module . . . proved to be successful in increasing knowledge among elementary students on Zakynthos and in reinforcing their locus of control and their understanding and concern regarding the sea turtle issue" (p. 57). While an increase in knowledge did occur, the reinforcement of locus of control and understanding and concern is speculation based on observed correlations. Similarly, the authors claimed that the conservation module can be used "on a long-term basis to create future citizenry that will be knowledgeable and motivated to support the purposes of the National Park" (p. 57). The results from this study alone are not enough to confidently express the statement above.

Although the authors seem to oversell their findings in the conclusion of the study, the study did seem to contain some valid results. The correlations between the variables of knowledge and understanding and concern suggest that as students' knowledge of an environmental issue such as sea turtle conservation increases, their understanding and concern may increase as well. An increase in concern about an environmental issue is a positive shift in attitude about science. The correlation between understanding and concern and locus of control suggests that a feeling of control increases with an increase in understanding and concern. It could be that a successful program could increase students' feelings of control and power in making environmental change, another positive attitudinal shift.

Summary

This collection of studies stimulates interest in the attitudinal impacts of extracurricular science experiences. Falk and Balling (1982) raised interesting questions about the relationships of novelty and age to the effectiveness of field trips in positively impacting student attitudes. Jarvis and Pell (2005) found that it is possible to positively impact student attitudes through a field trip, though this result is far from guaranteed. For example, female students' interest in space increased significantly after the field trip ($p < 0.01$), though there was no significant gain in male or female enthusiasm for science. Dimopoulos et al. (2008) highlighted correlations between knowledge and attitudes within an environmental education program, specifically between the variables of understanding and concern ($r = .638$, $p = .008$) (p. 55). As students gained knowledge, their understanding and concern increased as well.

The Role of Discussion

The following studies have been grouped due to their incorporation of discussion, also described as talk or discourse. Discussion can involve interaction between teachers and students as well as interaction among students. Waldrip, Reene, Fisher and Dorman (2008) examined the impact of teacher-designed interventions that incorporated discussion on students' perceptions of student-teacher interactions. Simon, Naylor, Keogh, Maloney and Downing (2008) analyzed the impacts of using puppets to promote student engagement and talk in elementary science classrooms. Jurow and Creighton (2005) dissected two K-1 teachers' use of improvisational discourse in science. These studies examined factors affecting students' perceptions and engagement in class discussions in science.

Waldrip et al. (2008) used a mixed methodology to observe the impact of teacher-designed interventions (incorporating whole-class discussions) on students' perceptions of interactions between students and their teachers in Queensland, Australia. The study involved 12 female primary science teachers and "297 students ranging from year 4 to year 7 [51% female]" (p. 219). The researchers were interested in observing student perceptions of eight characteristics of their teachers: "Leadership, Helping/Friendly, Understanding, Student Responsibility, Uncertain, Dissatisfied, Admonishing, and Strict" (p. 216). For clarification, "Uncertain" refers to a teacher who "behaves in an uncertain manner and keeps a low profile", "Dissatisfied" refers to a teacher who "expresses dissatisfaction, looks unhappy, criticises [AUS] and waits for silence", and "Admonishing" refers to a teacher who "gets angry, express[es] irritations and anger, and forbids and punishes" (p. 216). Perceptions were measured through the Questionnaire on

Teacher Interaction (QTI) which assesses the eight characteristics listed above.

The researchers conducted a pretest. Then teachers implemented a plan for improving students' perceptions for three months, after which a posttest was conducted. Each teacher developed her own intervention and "most teachers focused on developing group skills involving student choice within groups as a way to provide more responsibility . . . [and] had many whole-class discussions" (p. 221). Using the results of the posttest, the researchers chose "four classrooms that were indicative of the range of change in this study for further more intense interviews and observations" (p. 220). Interviews were conducted with students and teachers. Also after the interventions, classroom observations were made once a week for the next three months. The researchers calculated and analyzed descriptive statistics for pretest and posttest scores. The mean values for each survey scale were calculated for each class and the whole group.

As mentioned above, teachers conducted whole group discussions. The researchers found that "both the teachers and students found these extremely valuable especially when the students' opinions were genuinely valued and also acted upon by the teacher" (p. 221). Results varied in the four classes that were analyzed. For Class 1, the posttest showed very little change in perceptions (Mean scores (Pretest/Posttest): Leadership = 2.82/2.78, Helping = 3.19/3.14, Understanding = 2.85/2.88, Responsibility = 2.47/2.36, Uncertain = 1.60/1.59, Admonishing = 1.90/1.88, Strict = 2.32/2.23). However, positively, there was a slight decline in the "Dissatisfied" mean score (Pretest/Posttest = 1.77/1.51). Through interviews, the researchers found that "students felt that they were given many opportunities to discuss science and their opinions were really valued . . . [and] felt understood by the teacher" (p. 225). Class 2's posttest showed an increase in some negative perceptions (Uncertain = 1.60/1.83, Dissatisfied = 1.77/2.18, and Admonishing = 1.86/2.41) and a decrease in the Helping/Friendly scale (Pretest/Posttest = 3.10/2.65). The researchers suggested that this change could be due to a long service leave taken by the teacher and the inconsistency of multiple substitute teachers. The posttest in Class 3 showed increases in all of the positive characteristics (Leadership = 2.82/3.52, Helping/Friendly = 3.10/3.77, Understanding = 2.92/3.52, Student Responsibility = 2.44/2.89) and decreases in the negative characteristics of Admonishing and Strict (Admonishing = 1.80/1.26, Strict = 2.00/1.82). The posttest for Class 4, a class with positive initial perceptions, showed increases in all positive scales and decreases in all negative scales (Leadership = 3.32/3.70, Helping = 3.32/3.87, Understanding = 3.41/3.77, Responsibility = 2.65/3.29, Uncertain = 1.68/1.47, Dissatisfied = 1.90/1.15, Admonishing = 2.16/1.14, Strict = 2.50/1.80).

The findings of this study suggest that the interventions may have had an impact, either positive or negative, on student perceptions of teacher-student interactions. However, there is not much that can be said about what types of interventions may help to positively impact students perceptions, because the researchers did not thoroughly analyze or describe teachers' strategies. The focus of the study was on *if* teachers can make an impact rather than *how* they could do it. The study contains both strengths and weaknesses that must be taken into account.

The researchers' combination of quantitative and qualitative methods helped to both observe teachers' impacts on student perceptions and provide possible reasons for these impacts. The study of 12 classrooms allowed for a range of positive and negative impacts to be seen. Three months of weekly observations and interviews helped the researchers see how impacts and perceptions changed over time. Another strength of the study was the triangulation of students', teachers' and the researchers' (through observation and analysis) perceptions.

A weakness of the study was that the treatments were not uniform. This limited the generalization about how teachers can impact student perceptions. Along the same lines, the strategies (treatments) used by the teachers were not well described in the study. Another weakness of the study was in the selection of students for interviews. For Class 2, the researchers stated that the five students interviewed were "the best students in the class and somewhat stand alone from the rest of the group for being hard workers and motivated" (p. 226). This admission by the researchers suggests that they might not have interviewed students that represented a range of abilities or attitudes.

This study suggests that teachers may be able to have an impact on student perceptions of student-teacher interactions. These perceptions are a component of attitude and thus are important to this paper. Unfortunately, due to the limited scope of this study and its weaknesses, specific strategies to influence students' attitudes cannot be drawn from it. The qualitative interviews suggest that teachers and students found the use of discussion to be valuable, but no systematic, quantitative analysis of the impact of discussion is performed in the study. The study only hints that discussion could be valuable for influencing student perceptions.

Simon et al. (2008) studied the impact of the use of puppets in elementary science classrooms to promote student engagement and talk. The study was conducted with 16 teachers and their students in London and Manchester in the United Kingdom. Students ranged in age from seven to 11 years old and 51 were interviewed during the study. In each class, the researchers conducted a preliminary observation of a science lesson (including video recording), recording of small group activities of two groups and an interview with the teacher about instructional choices and talk in science.

After an orientation to the use of puppets and the development of characters, the researchers allowed the teachers to have several weeks of development with the puppets before they began observations and interviews. Then, the researchers observed another science lesson, this time with the utilization of puppets. Afterwards, teachers and some groups of students were interviewed. For the student interviews, "teachers selected a group of children who provided a representative sample of the class, and who demonstrated a mixed response to the puppets (some who appeared positive, some negative)" (p. 1234). Researchers analyzed video and audio tapes and identified and categorized types of talk that focused on reasoning and argument. They also measured the amount (time) of these types of talk during instances when students worked together. Chi-square tests were used to analyze differences in the number of instances of different types of talk and the amounts (time).

Through the analysis of recorded pre-puppet and puppet science lessons, the researchers found significant increases in children's use of argumentative responses and the teachers' use of argumentation (Frequency (Pre-puppet/Puppet): Children = 99/244, Teachers = 111/199, $p < 0.001$). They explained that "teachers' interaction with the children created more opportunities for engagement and challenge to thinking in the puppet lessons and most of this increase is attributed to argument used by the puppets" (p. 1241). Also, a significant decrease in children's use of recall responses created space for "more opportunities for children to develop reasoning within episodes of argumentation in puppet lessons" (Pre-puppet: 389, Puppet: 299, $p < 0.001$) (p. 1240). From interviews with students, the researchers found that "many of the children saw a strong connection between enjoyment and engagement" (p. 1244). Also, of the students interviewed, "seventeen children said that they felt more confident when speaking to the puppet" (p. 1244) than to the teacher.

If this study is assumed to be valid, the findings suggest that the use of puppets in science lessons may result in increased student engagement and in the quality of that engagement. By using puppets, a teacher may be able to change the nature of talk in his or her science classroom. As a component of a low-risk environment, some students may feel more comfortable speaking to a puppet. The use of puppets appeared to encourage students to develop more argumentative responses, a major component of critical thinking and scientific practice. The qualitative interviews suggest that students connected enjoyment and engagement. Some students felt more confident talking to the puppet than to the teacher. The strengths of this study suggest that these impacts are valid, while the weaknesses limit the generalization of the findings.

By observing a pre-puppet lesson for each class, the researchers were able to establish the base levels of reasoning and argumentation present in talk during science lessons. This preliminary look allowed for comparison and contrast with a lesson involving puppets. The researchers strengthened their study through the triangulation of data from students, teachers and researcher observation. By collecting data from different sources, the researchers built a comprehensive analysis based on multiple perspectives. When developing the coding system for the recorded lessons, two researchers independently coded a pre-puppet lesson and a puppet lesson and refined the coding system accordingly in order to improve the reliability of the coding system. A weakness in the research design was the lack of a control or comparison group. Without a control or comparison group, it is unclear whether or not the impacts observed in the study occurred as a result of the use of puppets. The findings could have been the result of another factor such as the children becoming more comfortable with their teachers as the school year progressed. Also, the researchers did not provide demographic information for the students. It is difficult to generalize these findings without knowing the racial, gender or socioeconomic make-up of the participants.

While the weaknesses of the study, stated above, limit generalization, the findings of this study suggest that the use of puppets may have positive impacts on some students' engagement and talk in science. The researchers do not examine student attitudes in great detail, though the interviews with students suggest that some experienced a change of attitude as a result of the intervention. The interplay of attitude and engagement is not examined in this study, but the quantitative results suggest a positive impact on the latter while qualitative methods hint at a change in the former after an intervention with puppets.

Jurow and Creighton (2005) examined two K-1 teachers' use of improvisational discourse in science to find strategies that they used to build on students' insights to enhance science discussions. The researchers used qualitative methods blending discourse analysis and ethnography to examine the two classes at "an elementary laboratory school located at a large, research university on the west coast . . . [with] a bilingual (Spanish-English) strand" (p. 279). Joint science lessons combined the two K-1 classes and involved "whole-class discussions and demonstrations, small-group activities led by the teachers, and hands-on, exploratory activities" (p. 280).

The researchers filmed 20 science lessons throughout one academic year. Using these recorded lessons, teacher interviews, field notes and student work samples, the researchers analyzed the lessons to discover instances of "emergent instruction" (p. 280). They defined emergent instruction as an instance when "students' unexpected insights were transformed by the teachers to lead instruction" (p. 280). Examples of emergent instruction were further analyzed to discover specific strategies the teachers used to scaffold student participation.

The researchers discovered individual examples of the teachers' utilization of student insights as well as some general trends that teachers followed. One example, from Ms. Rivera, involved the use of dance and humor to relate a scientific observation (the swirling of a solution of sand and water) with a dance the students know (the "Popcorn") (p. 284). Ms. Rivera engaged students with her humorous example while also teaching a valuable skill of connecting science with everyday occurrences. Also, the use of non-verbal communication helped to make the concept accessible to speakers of different languages.

In another example, Ms. Rosenthal discusses a student's idea with him as *his* idea, thus emphasizing his ownership of the idea. Two specific strategies used by the teachers in their improvisational discourse were "*positioning students as scientists* and *expanding scientific repertoires* [italics author]" (p. 293). Positioning students as scientists involved highlighting and reinforcing the identity of students as scientists with comments such as "All of you are chemists" and "[That's] what scientists do" (p. 291). Expanding scientific repertoires followed a process of connecting students' insights to scientific concepts in a manner accessible to all students, such as the example with Ms. Rivera above.

The results of this study suggest that teachers can utilize students' insights to engage them in scientific discourse. Strategies of positioning students as scientists and expanding scientific repertoires seemed to be effective at building and reinforcing scientific identities in students as well as making scientific concepts accessible to speakers of different languages (Spanish and English). However, before these inferences can be given credence, it is important to examine the strengths and weaknesses of the study.

One strength of this study was the longitudinal nature of the observation. The researchers observed science lessons for an academic year. Recording the lessons allowed for thorough analysis. The researchers strengthened their study through the triangulation of data sources including researcher observations, teacher interviews and sample student work. As a point of weakness, the researchers did admit that generalization (transfer) of the results was limited due to the uncommon setting of the laboratory school. They explained that the teachers "had more freedom than their public school counterparts to modify their day-to-day instruction and they had more time and institutional support for planning and reflecting collaboratively" (p. 294).

This limitation mentioned above is particularly important to public school teachers. The ability to enact the strategies used by these teachers may be limited by the work environment in a public school. That being said, the approaches could likely be modified to fit within the constraints of most science curriculum. While the researchers do not examine attitudes specifically, they do see a connection between the teachers' strategies and student engagement. It could be that these strategies bring about student engagement through a positive shift in attitudes and confidence in the students.

Summary

These studies provide compelling ideas involving the use of discussion in science instruction. Waldrip et al. (2008) suggested that impacting students' perceptions of teacher-student interactions (a primary component of class discussions) is possible, though they did not explicitly examine how this can be achieved. Simon et al. (2008) observed that through the use of puppets teachers were able to shift their teaching to be more student-centered allowing some students to develop more confidence and contribute more to discussions. Jurow and Creighton (2005) found patterns used by teachers in improvisational science discourse that helped to strengthen identity formation and student engagement. While it cannot be concluded from these studies alone that discussion (and specifically these techniques) will help improve students' attitudes and engagement, the studies certainly provide possibilities for future research and pursuit of ideas.

Chapter Summary

The aim of this critical review of literature in science education was to better understand trends in students' attitudes toward science and examine the effectiveness of various pedagogical approaches in positively impacting these attitudes. Change with Age, Including the Middle School Transition examined the change in attitudes with age. Several researchers saw a loss of enthusiasm for science with age (Pell & Jarvis, 2001; Reiss, 2004; Sorge, 2007). This is certainly a point of concern for elementary and middle school teachers. The transition from elementary to secondary school appears to be particularly problematic for students' attitudes (Braund & Driver, 2005; Sorge, 2007). Perhaps the bridging work mentioned by Braund and Driver (2005) could help to ease the transition and help students maintain positive attitudes.

Attitude, Interest and Gender explored gender differences in attitudes along with the impacts of various interventions on interest and attitudes in science and technology. Although no attitudinal impacts were observed, the Sisters in Science program, focused specifically on female science education, may have contributed to an increase in science-related skills (Hammrich et al., 2000). Boosting technological interest and self-efficacy through the use of technology education and integration seems to be a viable option for some student populations (Cady & Terrell, 2007; Mammes, 2004).

The Role of Confidence explored attitudinal variables related to confidence, such as theory of intelligence, effort beliefs, autonomy, competence and social-relatedness. Blackwell et al. (2007) found that students' theories of intelligence are correlated with motivational variables and achievement. An intervention to teach incremental theory was successful in transmitting understanding of the theory and positively impacting motivational variables and achievement. Kunter et al. (2007) suggested that correlations do exist between classroom management and interest, autonomy and competence.

Technology, Gender and Attitudes investigated the impacts of technological experiences on attitudes toward science, interest in scientific careers and attitudes about gender competence in technology. Nadirova and Burger (2008) found that the integration of technology had a positive impact on student attitudes toward science. Koszalka et al. (2005) discovered that the integration of human and web resources had a positive impact on students' career science interest. Beisser (2006) determined that technology integration positively impacted female students' gender competence beliefs.

Active Learning and Projects surveyed studies incorporating active or problem-based learning in science. Silver and Rushton (2008) pointed to students' desire to engage in hands-on, active exercises. Hugerat et al. (2004) found that the popular solar village project was perceived by students, teachers and parents alike to encourage student interest. Allen and Fraser (2007) showed a significant correlation that students who perceived more investigation in science class had more positive attitudes to science inquiry. Simons et al. (2004) showed that students who experienced problem-based learning generally expressed interest in similar future activities. Also, some spoke of autonomy as a benefit of PBL.

Cooperative Learning and Attitudes examined studies involving the impacts of social interaction and cooperative learning on the attitudes, perceptions and interests of students. Gläser-Zikuda et al. (2005) found that the ECOLE approach did not appear to have an impact on emotions, at least in the short-term. Chang and Muñoz (2006) discovered that the CDP appeared to enhance students' perceptions of autonomy and classroom supportiveness. Fields (2009) found that an astronomy camp offered opportunities for autonomy, peer interactions and validation of interest.

Extracurricular Science Opportunities explored the attitudinal impacts of extracurricular science opportunities. Falk and Balling (1982) raised interesting questions about the relationships of novelty and age to the effectiveness of field trips in positively impacting student attitudes. Jarvis and Pell (2005) found that it is possible to positively impact student attitudes through a field trip, though this result is far from guaranteed. Dimopoulos et al. (2008) highlighted correlations between the variables of understanding and concern in the context an environmental education program.

The Role of Discussion reviewed a collection of studies focused on the impacts of discussion on attitudes in science. Waldrip et al. (2008) discovered that impacting students' perceptions of teacher-student interactions can be achieved, though they did not explicitly examine how successful teachers achieved this aim. Simon et al. (2008) observed that through the use of puppets teachers were able to shift their teaching to be more student-centered allowing some students to develop more confidence and contribute more to discussions. Jurow and Creighton (2005) found patterns used by teachers in improvisational science discourse to utilize student ideas while strengthening identity formation and engagement.

Chapter one established a rationale for studying effective strategies for impacting students' attitudes in science. Chapter two provided a historical background of the study of students' attitudes and their impacts. Chapter three presented a critical review of literature in science education. The studies explored trends in students' attitudes toward science and examined the effectiveness of various pedagogical approaches in positively impacting these attitudes. Chapter four concludes the paper with a summary of findings, implications for teaching and suggestions for further research. The ideas in the first three chapters are synthesized in order to consider their implications for classroom instruction and develop effective strategies for positively impacting elementary students' attitudes in science.

Chapter IV: CONCLUSION

Introduction

Chapter one established the research purpose of discovering and building effective strategies for positively impacting elementary students' attitudes and interest in science. Establishing positive attitudes toward science is important because of the impacts of attitudes on achievement and career interest. It is also important because of the gaps that exist between male and female students in terms of interest, experience, achievement and career interest in science. Chapter two provided a historical background of the study of students' attitudes and their impacts. Early theorists professed that interest was a necessary prerequisite to learning. More recent research has examined interest as an important variable affecting motivation. Research on the gender achievement gap in science has suggested possible explanations for this gap including cultural, school and attitudinal factors (Kelly, 1981). Chapter three presented a critical review of literature in science education that explored trends in students' attitudes toward science and examined the effectiveness of various pedagogical approaches in positively impacting these attitudes. This research showed a decline in attitudes in science with age. Integrated technology programs were successful in increasing interest for some groups. Active, hands-on learning was popular with students. Chapter four now turns to implications for instruction. Chapter four concludes the paper with a summary of findings, classroom implications, areas for further research and a final conclusion.

Summary of Findings

Researchers studying age and attitudes in science noted some trends in the change of attitudes. Several researchers observed a decline in enthusiasm and attitudes toward science with age (Pell & Jarvis, 2001; Reiss, 2004; Sorge, 2007). The decline in attitudes and enthusiasm with age seems particularly prevalent at the transition between elementary and middle school (Braund & Driver, 2005; Sorge, 2007). Braund and Driver (2005) conducted their study for the purpose of informing "bridging work" between primary (elementary) and secondary schools aimed at eliminating this drop in enthusiasm and positive attitudes toward science. Students of all ages most enjoyed the active, hands-on elements of science (Pell & Jarvis, 2001). Reiss (2004) found that many of the students interviewed desired practical subjects relevant to their daily lives, teachers who took an interest in students and teachers who took time to explain subjects thoroughly.

The studies pertaining to gender offered interesting ideas for positively impacting female students' attitudes. Yanowitz and Vanderpool (2004) found that only a third of girls' workshops had a significant majority of participants who perceived women entered various scientific fields. Although no attitudinal impacts were observed, the Sisters in Science program, focused specifically on female science education, may have contributed to an increase in science-related skills (Hammrich et al., 2000). Boosting technological interest and self-efficacy through the use of technology education and integration seems to be a viable option for some student populations (Cady & Terrell, 2007; Mammes, 2004). Cady and Terrell (2007) found that integrating a technology program with science was more effective at improving female students' perceptions of computer importance and feelings of self-efficacy than teaching the subjects independently.

Studies of attitudinal variables related to confidence suggested possible pathways for boosting student confidence. Blackwell et al. (2007) discovered correlations between secondary students' endorsement of incremental theory and both positive effort beliefs and achievement in mathematics. An intervention to teach incremental theory was successful in transmitting understanding of the theory and positively impacting motivational variables and achievement. The more students endorsed incremental theory, the more they believed in the power of positive effort and achieved in mathematics. Kunter et al. (2007) found correlations between the classroom management elements of rule clarity and teacher monitoring and secondary students' feelings of autonomy and competence in mathematics.

Researchers examined the positive impacts of integrating technology into science curriculum. Nadirova and Burger (2008) found that an enriched science curriculum that integrated technology contributed to more positive attitudes and less gender disparity in attitudes. Koszalka et al. (2005) discovered that the integration of human and web resources had a positive impact on students' career science interest. Beisser (2006) concluded that through exposure to a technology program, female students had greater feelings of confidence and competence. Beisser pulled out strategies used by the teacher that may have had an impact on female students' feelings of confidence and competence. Some of these strategies are: "Longer Processing or Wait Time . . . Encouraging Construction Behavior for Both Genders . . . Specific Female Encouragement . . . [and] Whole Group Talks on Gender Diversity and/or Individual Differences" (p. 14).

Several studies examined the benefits of active learning, including project-based learning. Silver and Rushton (2008) found that despite enjoying science and hands-on activities, Year 5 students had little desire to become scientists. They attributed this finding in part to misconceptions that students held about scientists. Hugerat et al. (2004) surveyed students about the impacts of a solar village project on students' attitudes and interest. They discovered that most students, teachers and parents perceived a positive impact on students' interest in the project. Because the project is science-based, it is possible to say that an increased interest in the project is an increase in interest in science. Also, the students largely found the project to be relevant to their own lives. Allen and Fraser (2007) showed a significant correlation that students who perceived more investigation in science class had more positive attitudes to science inquiry. Simons et al. (2004) showed students who experienced problem-based learning generally expressed interest in similar future activities. Also, some spoke of autonomy as a benefit of PBL.

The integration of cooperative learning was shown to have several positive impacts on students' attitudes. In a qualitative study of a high school astronomy camp, Fields (2009) surmised that students' peer relationships helped to validate their interest in science, space and science careers. These peer relationships were cultivated through the use of cooperative learning. Chang and Muñoz (2006) studied a character education program that had a positive impact on elementary students' perceived autonomy and level of classroom supportiveness. A major component of the program was cooperative activities. The study analyzed students' feelings at school in general, not just in regards to science. It is likely that these attitudes would play a part in science. Gläser-Zikuda et al. (2005) found that the ECOLE approach did not appear to have an impact on emotions, at least in the short-term.

Several studies showed that extracurricular science activities have the potential to impact attitudes. Field trips are very popular with elementary students (Falk and Balling, 1982; Jarvis and Pell, 2005). Falk and Balling (1982) raised interesting ideas about the relationships of novelty and age to the effectiveness of field trips in positively impacting student attitudes. They found that while attitudes are generally positive, learning and behavior can differ greatly among students of different ages. Jarvis and Pell (2005) found that female students had a temporary increase in space interest as the result of a visit to the UK National Space Centre. So, it is possible to positively impact student attitudes through a field trip, though this result is far from guaranteed. In their interviews of students, the researchers found that "the post-school experience might have a dampening effect on their enthusiasm (p. 63). As a result, the researchers recommend conducting relevant activities before and after field trips. In a study of an in-school environmental education program, Dimopoulos et al. (2008) identified a correlation between the variables of 'knowledge' and 'understanding and concern'. This finding suggests that students who gain knowledge in an environmental program will likely gain understanding and concern as well.

The studies examining approaches that incorporate discussion revealed several potential benefits to student attitudes. Waldrip et al. (2008) studied 12 primary (Year 4 to Year 7) teachers' strategies to impact students' perceptions of interactions between students and teachers. In their analysis of the quantitative data, the researchers discovered that impacting students' perceptions of student-teacher interactions can be achieved, though they did not explicitly examine how successful teachers achieved this aim. Through qualitative interviews, the researchers recognized that students and teachers greatly valued class discussions. Simon et al. (2008) determined that the use of puppets had positive impacts on the attitudes of many students aged seven to eleven. Many students enjoyed the use of puppets and connected this enjoyment to engagement. Also, some students mentioned feeling more confident talking to the puppet, than they did talking to the teacher. Jurow and Creighton (2005) found that teachers perceived an improvement in engagement and attitudes as a result of valuing students' ideas and helping them form scientific identities.

Classroom Implications

The study of the impact of age on attitudes and interest in science produced several insights that have important implications for instruction. The desires for relevant topics expressed by secondary students in Reiss (2004) suggest a recommendation for practice. If teachers can design a science curriculum that is relevant to students' lives, both inside and outside of school, their teaching may be more effective at capturing students' interest and building enthusiasm. This newly relevant curriculum would hopefully curb, if not reverse, the decline in enthusiasm and attitudes toward science with age.

The substantial difference in attitudes between students on each side of the elementary-secondary transition suggests that students may benefit from some sort of bridge. Braund and Driver (2005) alluded to opportunities to work with secondary colleagues to ease the transition in science education. Creating interesting and engaging projects and curriculum to be worked on at both schools may help students retain enthusiasm and interest. As Dewey (1913) said "It is not enough to *catch* attention; it must be *held* [emphasis author]" (p. 91). Elementary and secondary teachers should work together to make sure that their students remain enthusiastic and interested throughout their science education.

Teaching science for gender equity requires a conscious, intentional approach. Yanowitz and Vanderpool (2004) found that many girls did not perceive women entering scientific fields. This could likely be the result of cultural influences (Hammrich et al., 2001; Kelly, 1981). To alleviate these misconceptions, teachers could expose their classes to female role models in contemporary science and throughout history. Bringing in female science professionals as guest speakers and teachers could also help deconstruct the stereotypes that students hold about scientists.

Integrating technology education and science showed potential for positively impacting female and male students' attitudes (Cady and Terrell, 2007; Mammes, 2004). With this understanding, teachers should integrate technology into science and other subjects, rather than teach it independently. Teaching about technology in context helps students understand more about *why* the technology is used, not just *how*. If students wish to continue studying science or pursue a science-related career, this foundational knowledge of technology is essential.

Confidence is a key component of attitude. Feelings related to confidence have an impact on students' motivation to study a subject, similar to the impacts described in Bandura's social cognitive theory of motivation (Gettinger & Stoiber, 1999). Classroom management, particularly the variables of rule clarity and monitoring, has the potential to impact students' feelings of autonomy and competence in middle school mathematics (Kunter et al., 2007). It could be assumed that similar connections could be found in elementary science. If this speculation is valid, elementary classroom management plans should prioritize rule clarity and monitoring in science. This can be achieved by working to make rules and norms clear to students while staying aware of what is going on in the class.

The research in confidence suggested that explicit teaching of incremental theory could positively impact positive effort beliefs and achievement in middle school mathematics (Blackwell et al., 2007). The impacts of these positive effort beliefs on achievement and learning have been substantiated by the research of prominent psychologists Weiner and Dweck (Gettinger & Stoiber, 1999). Teachers would benefit from surveying students to understand the nature of their theories of intelligence (entity vs. incremental). This information could help inform decisions about teaching methods. Teachers may want to focus feedback and praise on the actions and achievements of students, rather than innate abilities. Explicitly teaching incremental theory to students is another possibility, but more research is needed before this option is can be recommended.

Nadirova and Burger (2008) studied a curriculum that incorporated technology integration, greater access to technology, mentoring from community members and museum trips. A program like the one in this study connects school and community more closely. A close connection between school and community makes curriculum and classroom practices more relevant to students (Huerta, 2009). This eases their transitions between school and home and strengthens their learning, both of which can have positive impacts on attitude. Teachers should strive to create this connection by bringing in guest speakers and volunteers from the community including members of students' families.

Koszalka et al. (2005) discovered that the integration of human and web resources had a positive impact on students' career science interest. Career interest is valuable because as Herbart believed, interest "leads to meaningful learning, promotes long-term storage of knowledge, and provides motivation for further learning" (Schiefele, 1992, p. 151). So the career interest of an elementary school child has the potential to motivate him or her to continue studying and possibly pursue a career in science. For web resources, teachers should use videos, animations and interactive software programs online to get students interested in science and exploring science related careers. In the context of human resources, teachers should bring in experts in scientific fields to share information with students and serve as role models. They should give particular emphasis to inviting female science professionals, who can serve as role models for female and male students alike.

Beisser (2006) identified strategies that may have contributed to the observed increase in female students' feelings of confidence and competence. Implementation of these strategies constitutes general best practice and also supports female students in their scientific and technological endeavors. By giving students more wait time, teachers can allow more students to develop ideas and feel confident about sharing them. Specifically encouraging female students is essential due to their status as a historically marginalized group, particularly in science education. These conscious decisions may help to counteract cultural norms that discourage female students' participation in science (Hammrich et al., 2001; Kelly, 1981).

Silver and Rushton (2008) found that despite enjoying science and hands-on activities, Year 5 students had little desire to become scientists. Teachers should include plenty of hands-on activities in science in order to make it more enjoyable. It is important to develop a complex and comprehensive understanding of the real work that scientists do through research, multimedia and guest speakers. Perhaps this more accurate view of scientists' work will help increase science career interest in some students.

Simons et al. (2004) found that problem-based learning had a positive impact on some students' feelings of autonomy. Problem-based learning should be a part of every well-balanced elementary teacher's diverse ranges of methods. Teachers must make sure to allow ample time for learning and discovery. As students gain independence from the teacher and work with each other, autonomy will be strengthened. Again, considering Bandura's social cognitive theory, the connection between students' feelings of autonomy and motivation has the potential to strengthen as a result of more opportunities for autonomy.

Teachers should provide opportunities for students to work cooperatively in science. Students will be able to form relationships and share interests. In both cooperative and independent activities in the classroom, building character in students should be an area of focus. Treating each other with respect should be an expectation for students so that everyone feels supported. A friendly, respectful environment will provide fertile ground for students' positive attitudes to grow. An approach that includes cooperative learning has the potential to benefit student achievement as well (Gläser-Zikuda et al., 2005).

Extracurricular science activities can be used to positively impact student attitudes, though this result is far from guaranteed (Jarvis & Pell, 2005). Relevant field trips should be connected with in-class activities before and after the trip. This sustained engagement is beneficial to students' learning (Dewey, 1913). Interest will likely have a more lasting effect if students experience a subject for a longer time and in multiple contexts. Also, field trips and activities should be age appropriate in order to maximize learning and attitudinal gains. Students do not have to leave the classroom to engage in extracurricular science activities. Inviting guests to lead environmental education programs has the potential to both inform students and inspire them to act. Carrying a personal interest in the environment, in a subject so closely related to many scientific concepts, will hopefully provide motivation for students to learn more about science. This is an opportunity to spark the type of interest discussed in the *Revised Washington State K-12 Science Standards* (2008) mentioned in Chapter two.

Discussion shows potential for engaging students and positively impacting their attitudes in science. Teachers should work to lead balanced, engaging discussions in science. Jurow and Creighton (2005) recommended the discussion strategies of positioning students as scientists and expanding scientific repertoires to help build and reinforce scientific identities in students, as well as making scientific concepts accessible to speakers of different languages. The latter goal is particularly important in today's diverse public classrooms. An intentional approach to discussion will assure equitable participation and learning from a diverse range of students. The use of puppets and other play-like methods can help provide a low-stakes environment for students. This strategy has the potential to engage students and make them more willing to take risks in discussions. A low-stakes environment could better employ students' natural curiosity, as recommended in AAAS (1993).

Further Research

This paper attempted to find effective strategies for positively impacting elementary students' attitudes and interest in science. Many trends in attitudes and effective strategies were identified in this research. Studies came from a range of scholarly journals and involved diverse populations of students. Still, there are many more areas of research to explore in greater depth related to attitudes in science. Further research will likely result in a more comprehensive understanding and a more diverse repertoire of strategies.

The change in attitudes with age certainly merits further exploration. Most of the research in this paper pertained to *what* the change in attitudes was rather than *why* the change occurred. Discovering the causes of the decline of students' attitudes in science with age would be relevant to all teachers of science. Variables of interest may include maturation and student perceptions of difficulty, cultural relevance and practicality. The elementary-middle school transition, being particularly problematic for attitudes in science, would be a prime time on which to focus. Research could focus on what elementary and middle school teachers are doing to attempt to bridge this divide in attitudes. What projects or strategies have been effective?

Active, project-based and cooperative learning all hold potential for further research. This paper suggests that these methods can be effective, so the logical next step for research would be how to make them effective. What specific elements of each method of teaching help students' improve their attitudes and how can teachers structure their pedagogy to maximize these positive benefits? Certain methods will be more effective with certain cultural groups. Therefore, research involving a diverse range of students is essential to answering these questions. It would be valuable to examine the variable of achievement in addition to attitudinal variables.

The examination of extracurricular science activities was only preliminary. Future research could focus on how to make extracurricular activities have a positive impact on student attitudes. The variables of age, novelty and prior preparation would all be significant to this research. The developmental appropriateness of the location, duration and subject matter of extracurricular activities must be considered relative to the age of the students involved. Similar to the suggestions for active, project-based and cooperative learning, research would need to focus on diverse populations in order to pull out strategies that would work in diverse public school classrooms.

Only two studies focused on the attitudinal variable of theory of intelligence. Further research could focus on the impacts of theory of intelligence views and interventions. What are the impacts of theory of intelligence views on attitude, achievement and motivation? Why do these core beliefs impact these variables? How can teachers assess or teach theories of intelligence in order to better teach their students? It would be necessary to review studies from a wide range of researchers in order to develop a balanced perspective.

Another area of future research could be a deeper examination gender equity in science. Some researchers have found that female students have less positive attitudes than their male peers, while others have found the opposite. Regardless, the gender inequity in higher science education and careers is apparent (Kelly, 1981). What are the causes of this gender gap and what strategies can teachers use to reduce it? Identifying causes of gender inequity in public school classrooms will help teachers work to minimize their effects. Intentional strategies are essential for gender equity in the classroom.

Conclusion

Chapter one established the research purpose and rationale. The purpose of this paper was to discover and build effective strategies for positively impacting elementary students' attitudes and interest in science. Establishing positive attitudes toward science is important to the educational community as a whole because attitude and interest are closely correlated with achievement (Sorge, 2007, p. 33). Research indicates that students' attitudes impact both the quality of their work in school and their opinions of classes and jobs in science (Pell & Jarvis, 2001, p. 847). Despite this connection, there is sometimes a disconnect between students' enjoyment of science and their desire to pursue science-related careers (Silver & Rushton, 2008). The study of students' attitudes toward science is also relevant because of the gaps that exist between male and female students in terms of interest, experience, achievement and career interest in science (Hammrich et al., 2000).

Chapter two provided a historical background of the study of students' attitudes and their impacts. The discussion of students' attitudes and interest has its roots in many important historical developments in educational psychology and philosophy. The study of the role of interest in education has ebbed and flowed over the last 200 years. Herbart and Dewey considered interest to be a necessary prerequisite to meaningful learning (Dewey, 1913; Nenniger, 1992). After early research on interest, a relative lull occurred during the prominence of behaviorism (Krapp et al., 1992). A resurgence followed this lull as Bandura, Weiner and Dweck each studied the impacts of interest on motivation in education. Research on the gender achievement gap in science has suggested possible explanations for this gap including cultural, school and attitudinal factors (Kelly, 1981).

Chapter three presented a critical review of literature in science education that explored trends in students' attitudes toward science and examined the effectiveness of various pedagogical approaches in positively impacting these attitudes. Change with Age, Including the Middle School Transition examined the change in attitudes with age. Several researchers saw a loss of enthusiasm for science with age (Pell & Jarvis, 2001; Reiss, 2004; Sorge, 2007). This is certainly a point of concern for elementary and middle school teachers. The transition from elementary to secondary school appears to be particularly problematic for students' attitudes (Braund & Driver, 2005; Sorge, 2007). Perhaps the bridging work mentioned by Braund and Driver (2005) could help to ease the transition and help students maintain positive attitudes.

Attitude, Interest and Gender explored gender differences in attitudes along with the impacts of various interventions on interest and attitudes in science and technology. Although no attitudinal impacts were observed, the Sisters in Science program, focused specifically on female science education, may have contributed to an increase in science-related skills (Hammrich et al., 2000). Increasing technological interest and self-efficacy through technology education and integration seems to be a viable option for some student populations (Cady and Terrell, 2007; Mammes, 2004).

The Role of Confidence explored attitudinal variables related to confidence, such as theory of intelligence, effort beliefs, autonomy, competence and social-relatedness. Blackwell et al. (2007) found that students' theories of intelligence are correlated with motivational variables and achievement. An intervention to teach incremental theory was successful in transmitting understanding of the theory and positively impacting motivational variables and achievement. Kunter et al. (2007) suggested that correlations exist between classroom management and interest, autonomy and competence.

Technology, Gender and Attitudes investigated the impacts of technological experiences on attitudes toward science, interest in scientific careers and attitudes about gender competence in technology. Nadirova and Burger (2008) found that the integration of technology had a positive impact on student attitudes toward science. Koszalka et al. (2005) discovered that the integration of human and web resources had a positive impact on students' career science interest. Beisser (2006) determined that technology integration positively impacted female students' gender competence beliefs.

Active Learning and Projects surveyed studies incorporating active or problem-based learning in science. Silver and Rushton (2008) pointed to students' desire to engage in hands-on, active exercises. Hugerat et al. (2004) found that the popular solar village project was perceived by students, teachers and parents alike to encourage student interest. Allen and Fraser (2007) showed a significant correlation that students who perceived more investigation in science class had more positive attitudes to science inquiry. Simons et al. (2004) showed students who experienced problem-based learning generally expressed interest in similar future activities. Also, some spoke of autonomy as a benefit of PBL.

Cooperative Learning and Attitudes examined studies involving the impacts of social interaction and cooperative learning on the attitudes, perceptions and interests of students. Gläser-Zikuda et al. (2005) found that the ECOLE approach did not appear to have an impact on emotions, at least in the short-term. Chang and Muñoz (2006) discovered that a character development program appeared to enhance students' perceptions of autonomy and classroom supportiveness. Fields (2009) found that an astronomy camp offered opportunities for autonomy, peer interactions and validation of interest.

Extracurricular Science Opportunities explored the attitudinal impacts of extracurricular opportunities in science. Falk and Balling (1982) found that while attitudes toward field trips are generally positive, learning and behavior can differ greatly among students of different ages. Jarvis and Pell (2005) found that it is possible to positively impact student attitudes through a field trip, though this result is far from guaranteed. Dimopoulos et al. (2008) highlighted correlations between the variables of understanding and concern in the context an environmental education program.

The Role of Discussion reviewed a collection of studies focused on the impacts of approaches incorporating discussion on attitudes in science. Waldrip et al. (2008) discovered that impacting students' perceptions of teacher-student interactions can be achieved, though they did not explicitly examine how successful teachers achieved this aim. Simon et al. (2008) observed that through the use of puppets teachers were able to shift their teaching to be more student-centered allowing some students to develop more confidence and contribute more to discussions. Jurow and Creighton (2005) found patterns used by teachers in improvisational science discourse to utilize student ideas while strengthening identity formation and engagement.

Chapter four concluded the paper with a summary of findings, classroom implications and suggestions for further research. The research findings suggest important implications for classroom practice. The difference in attitudes between students on each side of the elementary-secondary transition suggests that students may benefit from a bridge (Braund and Driver, 2005). Elementary and secondary teachers should work together to ensure that their students' attitudes remain positive. Creating projects and curriculum to be worked on at both schools may help students retain enthusiasm and interest. Students' desires for relevant topics expressed in Reiss (2004) suggest that teachers should design curriculum that is relevant to students' personal lives in order to capture students' interest.

Teaching science for gender equity requires a conscious, intentional approach. Teachers should expose their classes to female role models in science today and throughout history. Bringing in female science professionals as guest speakers could help deconstruct students' stereotypes about scientists. Encouraging female students is essential due to their status as a historically marginalized group. Also, giving students more wait time allows more students to develop ideas and confidently share them.

Integrating technology into science and other subjects is more effective than teaching it independently. Teaching about technology in context helps students understand *why* the technology is used, not just *how*. Foundational knowledge of technology is essential for later study and careers and can help develop career interest. This integrated teaching of technology should include connections with community and family members in order to ease students' transitions between school and home.

Surveying students to understand the nature of their theories of intelligence (entity vs. incremental) can help inform decisions about teaching methods. Teachers may want to focus feedback and praise on the actions and achievements of students, rather than innate abilities. Teachers should work to make rules and norms clear to students while staying aware of what is going on in the class.

Teachers should include plenty of hands-on activities in science to spark interest. Problem-based learning should be a part of every well-balanced elementary teacher's diverse ranges of methods. Teachers must make sure to allow ample time for learning and discovery. Incorporating cooperative learning will allow for building of relationships, sharing of interest and respectful communication between students.

Relevant field trips should be connected with in-class activities before and after the trip. Interest will likely have a more lasting effect if students experience a subject for a longer time in multiple contexts. Field trips and activities should be age appropriate to maximize learning and attitudinal gains. Inviting guests to teach environmental education has the potential to inform students, spark interest in science and inspire them to act on environmental issues. Students should develop a comprehensive understanding of the work that scientists do through research, multimedia and guest speakers.

Teachers should work to lead balanced, engaging discussions in science in an effort to help create scientific identities in students and make concepts accessible to all students. An intentional approach to discussion will assure equitable participation and learning from a diverse range of students. The use of puppets and other play-like methods can help provide a low-stakes environment for students. This strategy has the potential to engage more students and make them more willing to take risks in discussions.

Further research in positively impacting attitudes and interest in science is recommended. Continued research on the change in attitudes with age could focus on the middle school transition and the variables of maturation and student perceptions of difficulty, cultural relevance and practicality. Additional exploration of how to make active learning, cooperative learning, discussion and field trips more effective in impacting student attitudes would be valuable to teachers. More research on gender equity would help identify and minimize causes of gender inequity in the classroom and work to establish equitable practices.

This paper showed the important role of attitudes in science education. Although these strategies vary, many of them stay close to significant pedagogical ideas. Get to know your students, utilize their prior knowledge and learning preferences and maintain a respectful, caring learning community in the classroom. Following these ideas, cultivate and nurture interest and positive attitudes in your students in science and other subjects.

This intentional approach will allow each child to develop the skills, knowledge and positive attitudes he or she needs to choose from a full range of future educational and professional opportunities.

REFERENCES

Akerson, V. L. & Hanuscin, D. L. (2007). Teaching nature of science through inquiry: Results of a 3-year professional development program. *Journal of Research in Science Teaching 44*(5) 653-680.

Allen, D., & Fraser B. J. (2007). Parent and student perceptions of classroom learning environment and its association with student outcomes. *Learning Environments Research 10*(1) 67-82.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. Retrieved April 13, 2009, from http://www.project2061.org/publications/bsl/online/index.php?home=true

Beisser, S. R. (2006). An examination of gender differences in elementary constructionist classrooms using Lego/Logo instruction. *Computers in the Schools 22*(3/4) 7-19.

Blackwell, L. S., Trzesniewski, K. H., & Dweck, C. S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development 78*(1) 246-263.

Braund, M., & Driver, M. (2005). Pupils' attitudes to practical science around the KS2/3 transition. *Education 3-13 33*(2) 20-26.

Cady D., & Terrell, S. R. (2007). The effect of the integration of computing technology in a science curriculum on female students' self-efficacy attitudes. *Journal of Educational Technology Systems 36*(3) 277-286.

Chang, F. & Muñoz, A. (2006). School personnel educating the whole child: Impact of character education on teachers' self-assessment and student development. *Journal of Personnel Evaluation in Education 19* 35-49.

Denissen, J. J. A., Zarret, N. R., & Eccles, J. S. (2007). I like to do it, I'm able, and I know I am: Longitudinal couplings between domain-specific achievement, self-concept, and interest. *Child Development, 78*(2), 430-447.

Dewey, J. (1913). *Interest and effort in education*. Cambridge: The Riverside Press.

Dimopoulos, D., Paraskevopoulos, S., & Pantis, J. D. (2008). The cognitive and attitudinal effects of a conservation education module on elementary school students. *The Journal of Environmental Education 39*(3) 47-61.

Falk, J. H., & Balling, J. D. (1982). The field trip milieu: Learning and behavior as a function of contextual events. *Journal of Educational Research 76*(1) 22-28.

Fields, D. A. (2009). What do students gain from a week at science camp? Youth perceptions and the design of an immersive, research-oriented astronomy camp. *International Journal of Science Education 31*(2) 151-171.

Gettinger, M., & Stoiber, K. C. (1999). Excellence in teaching: Review of instructional and environmental variables. In Reynolds, C. R., & Gutkin, T. B. (Eds). *The handbook of school psychology* (pp. 933-212). New York: John Wiley & Sons, Inc.

Gläser-Zikuda, M. Fuß, S., Laukenmann, M., Metz, K., & Randler, C. (2005). Promoting students' emotions and achievement: Instructional design and evaluation of the ECOLE-approach. *Learning and Instruction 15* 481-495.

Hammrich, P. L., Richardson, G. M., & Livingston, B. D. (2000). Sisters in Science: Confronting equity in science and mathematics education. *Journal of Women and Minorities in Science and Engineering 6*(3) 207-220.

Hammrich, P. L., Richardson, G., & Livingston, B. (2001). The Sisters in Science Program: A three year analysis. Retrieved March 15, 2009, from ERIC database.

Huerta, G. C. (2009). *Educational foundations: Diverse histories, diverse perspectives*. Boston: Houghton Mifflin Company.

Hugerat, M., Haiyan, S., Zadik, R., Zidani, S., Zidan, R. & Toren, Z. (2004). The impact of implementing an educational project, the solar village, on pupils, teachers, and parents. *Journal of Science Education and Technology. 13*(2) 277-283.

Jarvis, T., & Pell, A. (2005). Factors influencing elementary school children's attitudes toward science before, during, and after a visit to the UK National Space Centre. *Journal of Research in Science Teaching 42*(1) 53-83.

Jurow, A. S., & Creighton, L. (2005). Improvisational science discourse: Teaching science in two K-1 classrooms. *Linguistics and Education 16* 275-297.

Kelly, A. (1981). *The missing half: Girls and science education*. Manchester: Manchester University Press.

Koszalka, T. A., Grabowski, B. L., & Darling, N. (2005). Predictive relationships between web and human resource use and middle school students' interest in science careers: An exploratory analysis. *Journal of Career Development 31*(3) 171-184.

Krapp, A., Hidi, S., & Renninger, K. A. (1992). Interest, learning, and development. In Renninger, K. A., Hidi, S., & Krapp, A. (Eds.), *The role of interest in learning and development* (pp. 3-25). Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.

Kunter, M., Baumert, J., & Köller, O. (2007). Effective classroom management and the development of subject-related interest. *Learning and Instruction 17* 494-509.

Mammes, I. (2004). Promoting girls' interest in technology through technology education: A research study. *International Journal of Technology and Design*

Education 14 89-100.

Nadirova, A. & Burger, J. (2008). Evaluation of elementary students' attitudes toward science as a result of the introduction of an enriched science curriculum. *The Alberta Journal of Educational Research. 54*(1) 30-49.

Nenniger, P. (1992). Task motivation: An interaction between the cognitive and content-oriented dimensions of learning. In Renninger, K. A., Hidi, S., & Krapp, A. (Eds.), *The role of interest in learning and development* (pp. 183-212). Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.

Office of Superintendent of Public Instruction (2008). *Revised Washington State K-12 science standards*. Olympia, WA: Retrieved April 15, 2009, from http://www.k12.wa.us/CurriculumInstruct/Science/pubdocs/WAScienceStandards.pdf

Pell, A., & Jarvis, T. (2001). Developing attitude to science education scales for use with primary teachers. *International Journal of Science Education*. *25*(10) 1273-1295.

Reiss, M. J. (2004). Students' attitudes towards science: A long-term perspective. *Canadian Journal of Science, Mathematics, & Technology 4*(1) 97-109.

Schiefele, U. (1992). Topic interest and levels of text comprehension. In Renninger, K. A., Hidi, S., & Krapp, A. (Eds.), *The role of interest in learning and development* (pp. 151-182). Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.

Schiefele, U., Krapp, A., & Winteler, A. (1992). Interest as a predictor of academic achievement: A meta-analysis of research. In Renninger, K. A., Hidi, S., & Krapp, A. (Eds.), *The role of interest in learning and development* (pp. 183-212). Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.

Shymansky, J. A., Yore, L. D., & Anderson, J. O. (2000). A study of changes in students' science attitudes, awareness and achievement across three years as a function of the level of implementation of interactive-constructivist teaching strategies promoted in a local systemic reform effort. *Paper presented at the Annual Meeting of the National Association for Research in Science Teaching*. New Orleans, LA.

Silver, A. & Rushton, B. S. (2008). Primary-school children's attitudes towards science, engineering, and technology and their images of scientists and engineers. *Education 3-13 36*(1) 51-67.

Simon, S., Naylor, S., Keogh, B., Maloney, J. & Downing, B. (2008). Puppets promoting engagement and talk in science. *International Journal of Science Education 30*(9) 1229-1248.

Simons, K. D., Klein, J. D., & Brush, T. R. (2004). Instructional strategies utilized during the implementation of a hypermedia, problem-based learning environment: A case study. *Journal of Interactive Learning Research 15*(3) 213-233.

Sorge, C. (2007) What happens? Relationship of age and gender with science attitudes from elementary to middle school. *Science Educator. 16*(2) 33-37.

Spring, J. H. (2005). *The American school: 1642-2004*. New York: McGraw-Hill.

Waldrip, B., Reene, P., Fisher, D., & Dorman, J. (2008). Changing primary students' perceptions of teacher interpersonal behaviours in science. *Research in Science Education 38* 213-235.

Yanowitz, K. L. & Vanderpool, S. S. (2004). Assessing girls' reactions to science workshops. *Journal of Science Education and Technology. 13*(3) 353-359.