ABSTRACT

SCIENCE FAIRS AND SCIENCE OLYMPIAD: INFLUENCE ON STUDENT SCIENCE INQUIRY LEARNING AND ATTITUDES TOWARD STEM CAREERS AND COURSEWORK

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Thousands of middle school students participate in science competitions such as science fairs and Science Olympiad yearly, but little is known about the effects of their participation on their attitudes toward science, technology, engineering and mathematics (STEM) coursework and careers. Even less is known about whether they increase students’ understanding of the practices of scientific inquiry. In this study, 86 seventh-grade students from eight schools who participated in either science fair or Science Olympiad competitions were assessed regarding their attitudes toward STEM coursework and careers and the extent of their science inquiry skills. Quantitative data were collected through pre- and post-competition written assessments. Qualitative data were collected through post-competition focus groups.

Both groups increased their understanding of science inquiry as a result of their participation in science competitions. Student attitudes toward STEM coursework and careers were generally positively influenced by their participation in science competitions. However, there was a subgroup of science fair participants for which the opposite was true.
The strengths of Science Olympiad programs were the opportunities to study science topics on a deep level, to work with teammates, and to compete. However, there was little student choice at the schools studied because the coaches chose the teams and generally assigned students to particular Science Olympiad events. The level of science inquiry varied according to event. Strengths of the science fair programs were student choice regarding topics and a focus on science inquiry. However, the level of stress experienced by some students, and the negative attitudes toward science that resulted, called into question the appropriateness of engaging in a project of the length and complexity of a typical science fair project with this age group.

Recommendations for Science Olympiad competitions are adding events that allow more student choice and deeper engagement with science inquiry. Science fair students may benefit from engaging in several small projects, rather than one large project, and from working with a partner or a small group. It was found that for most students, science competition participation had a positive influence on their understanding of science inquiry and attitudes toward STEM coursework and careers.
SCIENCE FAIRS AND SCIENCE OLYMPIAD: INFLUENCE ON STUDENT SCIENCE INQUIRY LEARNING AND ATTITUDES TOWARD STEM CAREERS AND COURSEWORK

BY

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Paul Kelter
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Finally, I would like to thank my family for their support and tolerance over the many years that it took to complete this project.
DEDICATION

I dedicate this work to my sons, Alex and Kevin, who never wavered in their belief that I could fulfill my dream of earning a doctorate.
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CHAPTER 1

BACKGROUND

Introduction

In recent years, attention has been focused on the need for more American students to enter careers relating to science, technology, engineering, and mathematics (STEM) fields in order for the United States to remain economically and technologically competitive on a global scale (STEM Education Coalition, 2012). However, in order for students to aspire to these careers, they need to prepare in high school and college by taking a rigorous course of study in STEM subjects. R. D. Simpson, Koballa, Oliver, and Crawley (1994) used the metaphor of a STEM career pipeline, in which students might leak based on the curricular choices they make in high school. Therefore, it would seem that the key to increasing the number of students entering STEM fields might be to engage their interest while in middle school (Maltese & Tai, 2010). Engaging student interest in STEM while in middle school is especially important because of the extensive academic preparation required to enter a STEM career. The State of Illinois requires students to take 3 years of math and 2 years of science coursework in order to graduate from high school (ISBE, 2009). However, in order to be admitted to an engineering or science program at the University of Illinois, students need to have taken 4 years of math and 4 years of laboratory science in high school.
(University of Illinois, 2012). While increasing student interest in STEM fields may help to fill the pipeline, students need science inquiry skills and understanding in order to persevere in their pursuit of STEM careers (National Research Council, 2000), and they need to start preparing in middle school for a rigorous high school program. Cleaves (2005) found that common reasons that students give for not pursuing science courses are lack of exposure to opportunities in science careers and a lack of confidence in their science aptitude. Science competitions for middle school students, such as science fairs and Science Olympiad, may play a role in encouraging students to not only enter the STEM career pipeline but also to persist and be successful by providing them with an authentic science inquiry experience at a critical age.

Inquiry is at the heart of the way science is conducted. Scientists engage in inquiry through asking questions about the natural world, gathering evidence, then constructing explanations that follow logically from the evidence (Anderson, 2007). In 2012, the National Research Council (NRC) published *A Framework for K-12 Science Education* (Achieve, Inc., 2012), the foundational document from which the Next Generation Science Standards (NGSS) were developed (NGSS Lead States, 2013). In *A Framework for K-12 Science Education* (Achieve, Inc., 2012) “Scientific and Engineering Practices,” (National Research Council, 2012, p. 3) are defined and described in detail, with every performance expectation in the NGSS cross-referenced to the appropriate scientific and engineering practice (NGSS Lead States, 2013). Therefore, students are expected to understand how to ask a scientific question, plan and conduct a scientifically valid investigation, make observations, analyze and interpret the data they obtain, and communicate their results.
These practices align very well with the characteristics of science inquiry as defined by Yager (2009) and the National Research Council (2000).

Science competitions may provide a venue through which middle school students have an opportunity to engage in science inquiry, gain experience in the practices of science and engineering (National Research Council, 2012), and prepare for future STEM coursework and careers (Illinois Junior Academy of Science, n.d.; Science Olympiad, Inc., 2013). In a typical science fair, students choose a topic, write a literature review, formulate a hypothesis, design and perform an experiment, and analyze and interpret their results. The final product includes a written paper, a display board, and an oral presentation. At the fair, students present their work to a panel of judges and receive a rating. Fairs are held at the school, regional, state, and national levels, with advancement through the various levels determined by the judges’ ratings (Illinois Junior Academy of Science, 2012). Even though the high-profile international fairs, such as the Intel International Science and Engineering Fair (Society for Science and the Public, 2012), focus on high school students, the majority of competitors in state-level science fairs in Illinois are middle school students (Illinois Junior Academy of Science, n.d.). The Illinois Junior Academy of Science (IJAS) links its goals for students to the Illinois Learning Standards for Science, which includes goals for understanding science inquiry as well (Illinois State Board of Education, 1997). The criteria used by judges at IJAS fairs provide a clear connection to how well the students apply the principles of scientific inquiry to the development of their project and the rating they receive (Illinois Junior Academy of Science, 2012). During the 2013-2014 school year, 332 schools were registered as members of the IJAS, and approximately 1000
students participated in the in the state-level fair at State Exposition (Illinois Junior Academy of Science, n.d.).

Another science competition available to middle and high school students is Science Olympiad, in which participants work together as a team to meet science challenges. According to the 2013-2014 brochure, 7,000 teams from all 50 states participated in Science Olympiad competitions (Science Olympiad, Inc., 2013). These competitions are held at the local, regional, and national level, with team scores determining advancement. As with science fairs, even though there are a significant number of high school participants, the majority of the contestants are middle school students. Science Olympiad explicitly states that a key goal of its program is to encourage more students to enroll in science courses and to pursue science careers as well as increasing student understanding of how science works (Science Olympiad, Inc., 2013).

Science fairs and Science Olympiad are events that have a long tradition and involve many students. It would seem to be logical that these events might increase the number of students in the STEM career pipeline by developing their interest and skills. Whether they really achieve this goal has not been well studied.

Problem

There is disagreement among parents and teachers about whether involvement in science competitions such as science fairs and Science Olympiad is beneficial or detrimental to middle school students, based on anecdotal evidence or parents’ and teachers’ experiences (Craven & Hogan, 2008). What little research that does exist tends to
focus on middle and high school student attitudes (Abernathy & Vineyard, 2001; Czerniak, 1996; Czerniak & Lumpe, 1996). The governing organizations of science fairs and Science Olympiad state that their goals for students are increasing student knowledge of the process of science inquiry and encouraging students to pursue science courses, and ultimately, science careers (Illinois Junior Academy of Science, 2012; Science Olympiad, Inc., 2013). Research is needed to determine whether these goals are being met for middle school students. Over the years, a significant amount of time and energy has been spent by students, parents, and teachers on this educational practice that has a limited research base.

Purpose

One purpose of this study was to determine if middle school students increase their understanding of scientific inquiry as a result of participating in science fair and Science Olympiad competitions.

The second purpose of this study was to examine the influence of participation in science fair and Science Olympiad on middle school students’ attitudes toward STEM subjects and careers.

Research Questions

1. Does formal science competition participation in middle school promote an increase in the understanding of science inquiry?
2. Does formal science competition participation increase middle school student interest in studying STEM subjects and pursuing STEM careers?

3. Are there differences in the understanding of science inquiry among middle school students who participated in science fairs and those who participated in Science Olympiad?

4. Are there differences in attitudes toward STEM subjects and careers among middle school students who participated in science fairs and those who participated in Science Olympiad?

**Conceptual Framework**

In order for a student to enter a STEM career, he or she first needs to successfully complete a rigorous academic program in high school and college. This success is contingent upon the student having not only the interest and desire to enter a STEM field but also having the knowledge and skills to apply science and engineering practices in his or her coursework. In a study by the National Center for Education Statistics (NCES; Chen, 2013), the attrition rate of college students who entered STEM majors was higher for students who took fewer science and math courses in college and/or were less successful in those courses. Because of the length of the training required to enter a STEM field, this interest and desire, and knowledge and skill, need to be acquired well before a student enters high school. Science competitions, such as science fairs and Science Olympiad, may provide middle school students an opportunity to gain these skills and attitudes in ways that are not usually available in the regular classroom.
Figure 1 is a visualization of how science competitions may contribute to student interest and success in pursuing STEM careers. Science fairs and Science Olympiad serve as the foundation of the framework. Both of these competitions have goals for students that include improving science inquiry knowledge and skills as well as increasing interest in STEM careers (Illinois Junior Academy of Science, 2012; Science Olympiad, Inc., 2013). Those goals are represented in the next tier of boxes. Science inquiry knowledge and skills, such as asking questions, gathering evidence, and formulating explanations based on the evidence, are key skills needed for success in STEM careers (Anderson, 2007). Skills alone are not enough to ensure that students will aspire to STEM careers; they also need to have an interest in those careers. The essential factors that contribute to student interest in STEM careers are the encouragement of adults (Maltese & Tai, 2010) and opportunities for hands-on, real-world experiences (Hazari, Sonnert, Sadler, & Shanahan, 2010; Kanter, 2010). Both are integral features of science fairs and Science Olympiad. After students have the skills and interest in STEM careers, they need to take courses to prepare for those careers, represented by the next tier’s box (University of Illinois, 2012). Successful completion of the needed coursework should result in a student reaching the next tier, a STEM career.

Significance

Thousands of middle school students participate in science competitions every year, but little is known about the effects of their participation on their attitudes toward STEM coursework and careers. Even less is known about whether the competitions increase their
Figure 1: Conceptual Framework

understanding of the practices of scientific inquiry. This study will contribute to filling that gap. Results from this study could be used to make recommendations for changes, if needed, in the way that science fairs and Science Olympiad are structured so they will better fulfill the stated goals of their respective organizations and meet the needs of the students.

Definitions

Science fairs—competitions for middle and high school students for which individual students (or small groups) do background research, design and conduct an experiment, collect and analyze data, reach conclusions, and communicate their results in a public
forum through a written paper, a presentation board and/or other media, and an oral presentation.

Science Inquiry—a definition based on the practices for K-12 classrooms considered essential by the National Research Council (2012); they are

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information. (p. 49)

Science Olympiad—programs for students in Grade K-6 and competitions for middle and high school students sponsored by Science Olympiad, Inc. (Science Olympiad, Inc., 2013).

Science, technology, engineering and mathematics (STEM)—relating to science, technology, engineering, and mathematics (STEM Education Coalition, 2012).

Delimitations

This study assessed on 86 students in Grade 7 from eight schools, six in the Chicago metropolitan area, one rural school, and one suburban school in the Metro East (St. Louis) region. Schools generally offer either a science fair or a Science Olympiad team, but not both. Therefore, the 86 students were divided into groups by school and event. Grade 7 is the lowest grade at which students can participate in IJAS-sanctioned science fairs, while Science Olympiad is a K-12 program. Therefore, Grade 7 was chosen for this study in order to assess the students at the youngest age possible.
Limitations

The chief limitation of the study was the small sample size. Another difficulty was matching the schools and participants demographically, including their socioeconomic status. Prior and concurrent science instruction, especially if the Science Olympiad students had participated in that competition prior to seventh grade, complicated comparisons. In addition, the lack of schools willing to serve as a control group (i.e. by attending no science competitions) limited the conclusions that could be drawn from the study.

Methodology

A sequential mixed method study, as described by Creswell (2008), was performed, with the collection of quantitative data followed by the collection of qualitative data. The subjects were seventh-grade students in suburban and rural schools in Illinois. There were two groups: those participating in science fairs and Science Olympiad participants. Quantitative data about student science inquiry skills were collected using a grade-level appropriate modified version of the Scientific Inquiry Literacy Test (Wenning, 2007b): the Middle School Science Inquiry Literacy Test that was developed by the researcher. Attitudes toward STEM coursework and careers were collected using the Science Opinion Survey (Gibson, 2008). Follow-up data were collected through focus groups (Barbour, 2008). The quantitative data for student-inquiry skills assessment and the science attitude inventory was analyzed using descriptive statistics. In addition, differences between the
groups who took the Middle School Science Inquiry Literacy Test were analyzed using the Independent Samples Mean Test (Field, 2009; Green & Salkind, 2005). Differences between the groups who took the Science Opinion Survey were analyzed using the Mann-Whitney U test (Green & Salkind, 2005), while differences within groups for both assessments were analyzed using the Wilcoxon Signed Ranks Test (Field, 2009; Green & Salkind, 2005). The focus group data was analyzed according to the protocol described by Maxwell (2005), in which the students’ comments were categorized as “organizational” or “substantive” (p. 97), and relationships between the categories were investigated.

Organization

This dissertation has five chapters. This chapter introduces the study by detailing the problem and purpose of the study and introducing the conceptual framework and the methodology. Chapter 2 reviews the existing research about science fairs, Science Olympiad, student interest in STEM coursework and careers, and the role of scientific inquiry in student science learning. Chapter 3 describes the research methodology, data collection, and analysis tools. In Chapter 4, the results from the pre and post surveys of student attitudes, pre and post assessments of student science inquiry skills, focus groups, and interviews are presented and discussed. The final chapter includes analysis, findings, and implications for science education practice, as well as recommendations for future research.
CHAPTER 2

LITERATURE REVIEW

Introduction

Science competitions, such as science fairs and Science Olympiad, are a common feature of the educational landscape. In particular, science fairs are a tradition in many schools and anathema in many others. For some, they evoke images of rows of trifold boards presided over by nervous 13-year-olds. For others, they represent memories of many happy hours spent delving into a fascinating topic. In my informal conversations with teachers regarding their attitudes toward science fairs, the reactions ranged from firm support to “I wish I could, but there is too much content to cover” to abject horror. For parents, science fairs often instill a sense of dread. A quick search of the catalog at my local library yielded over 50 books to help parents and students design successful projects.

In the press, it is not uncommon to encounter critiques of science fairs such as Craven and Hogan’s (2008) plea to reform science fairs, written after their encounter with a student whose father had done her project for her. At the White House Science Fair in 2012, President Obama stated that what the students were doing would “make a bigger difference over the life of our country than just about anything” (Calmes, 2012). However, The New York Times, as reported in Curriculum Review, stated that even though science fairs are supported by President Obama, fewer students are participating (Science Fairs in Trouble,
2011). For example, 244 schools participated in the Los Angeles County Science Fair in 2001, but only 185 schools participated in 2011 (Science Fairs in Trouble, 2011). Teachers cited pressure to cover standards as the reason for the decline. Bowen and Bencze (2009) noted that coverage of science fairs in the press generally focused on the competition and corporate sponsorship aspects rather than the students and their projects. Given the pervasiveness and long history of science competitions, it stands to reason that their effects on student achievement and motivation would be thoroughly studied. However, when Jill Slisz embarked on a study of science fairs in 1989 as a research project in secondary education at Indiana University South Bend, she found that there was very little research available. In fact, she found that most of the articles that had been published consisted of opinion pieces and how-to articles and even these were very limited. During the last 20 years, very little has been added to the research literature. The research base for Science Olympiad is even smaller, consisting of only a few articles and doctoral dissertations.

Everyone involved seems to assume that science competitions are good (or bad) for students based on anecdotal evidence or their own experiences. The little research that does exist tends to focus on student attitudes. A much needed area of research is what educators expect students to learn from science fairs and Science Olympiad and what the participants actually learn from the experience. Finally, while it would seem to be reasonable to expect that successful science fair or Science Olympiad participation would lead to an interest in pursuing a science career, there are only a few studies about related student motivation and achievement. Over the years, a lot of time and energy has been spent on educational practices that have a small basis in research. It is time to rectify this situation.
Science fair competitions have a long history in the United States. In 1921, the journalist E.W. Scripps founded Science Service, a news syndication service that aimed to bridge the gap between the scientific community and the public. In 1941, Science Service teamed with the American Institute to found Science Clubs of America, which grew to 800 clubs in 48 states (Schock, 2011). The following year, the Science Talent Search (STS) was created in partnership with Westinghouse; its goal was to encourage youth to pursue science and engineering careers. The popularity of this program led to the first National Science Fair, held in Philadelphia in 1950 (Society for Science and the Public, 2012). This event became the Intel International Science and Engineering Fair in 1998 and has since grown to include participants from 48 states and 70 countries and regions (Society for Science and the Public, 2012). The American Junior Academy of Sciences is a nonprofit, all-volunteer organization that also sponsors science competitions and is affiliated with the National Association of Academies of Science. It also holds meetings for students in conjunction with the meetings of the American Association for the Advancement of Science (American Junior Academy of Sciences, n.d.). In Illinois, the Illinois Junior Academy of Science sponsors regional science fair competitions for middle and high school students, with the top students advancing to the State Exposition held in May at the University of Illinois at Urbana-Champaign (IJAS, 2012).

Science Olympiad, Inc. is a national organization that has been sponsoring science competitions for over 25 years (Science Olympiad, Inc., 2013). During the 1970s and early 1980s, several states had Science Olympiad-type competitions. Dr. Gerard Putz and John C. Cairns were instrumental in organizing the first Science Olympiad National Tournament.
which was held at Michigan State University in 1985. This first national tournament was sponsored by the United States Army Recruiting Command, and 17 states participated (Science Olympiad, Inc., 2013). According to the 2013-2014 Science Olympiad brochure, there are now 7,000 teams from all 50 states (Science Olympiad, Inc., 2013).

**Overview of Science Fair Competitions**

A typical science fair project is very similar in concept to a scientific study that would be conducted by a professional scientist (Illinois Junior Academy of Science, 2012). The students write a literature review about their topic, formulate a hypothesis, design and conduct an experiment to test the hypothesis, interpret the results, and form a conclusion that includes possible sources of error and suggestions for further research. In order to communicate their results to an audience, the students create a poster, similar to posters that are presented at a poster session at a scientific conference, and prepare an oral presentation. Where science fairs differ from professional research is the competition aspect. At a science fair, middle school and high school students present and discuss their work with a panel of volunteer judges. The judges give the students feedback about their work, and depending on the governing organization of the particular fair, ratings, awards, prizes, and chances to advance to the next level are given (Illinois Junior Academy of Science, 2012). Science fairs are most often held at individual schools. However, there are a few organizations that sponsor state, regional, and national competitions.
In 2012, the National Research Council published *A Framework for K-12 Science Education* (Achieve, Inc., 2012), which is the foundational document from which the Next Generation Science Standards (NGSS) were developed (NGSS Lead States, 2013). In *A Framework for K-12 Science Education* (Achieve, Inc., 2012), the NRC has identified three dimensions of science education: “scientific and engineering practices,” “crosstcutting concepts,” and “disciplinary core ideas,” (National Research Council, 2012, p. 3), that the standards address. Each individual performance expectation (i.e., standard) in the NGSS is cross-referenced to these three dimensions. (NGSS Lead States, 2013). In terms of “scientific and engineering practices” (National Research Council, 2012, p. 3) students are expected to understand (among other ideas) how to ask a scientific question, plan and conduct a scientifically valid investigation, analyze and interpret the data they obtain, and communicate their results. Science fair participation would seem to be a logical way for students to gain these understandings.

The American Junior Academy of Science is the governing organization for a national science fair that draws high school-aged participants from several state science fairs (National Association of Academies of Science and American Junior Academy of Science, n.d.). The organization’s website has a detailed description of the process for entering its competition but does not articulate goals for student learning. The Illinois Junior Academy of Science provides a mission statement in its policy manual (Illinois Junior Academy of Science, 2012); which states that the mission of their science fair is to help students understand that science is a way to investigate the world rationally and systematically and that logic and critical
thinking are integral parts of the process. The manual includes links to the Illinois Learning Standards (Illinois State Board of Education, 1997), relating to mathematics, English/language arts, and science. The mathematics goals pertain to data collection and analysis, while the English/language arts goals relate to writing and speaking to communicate information. The science goals focus on inquiry and experimentation as well as connections between science, technology, and society (Illinois State Board of Education, 1997). The judging criteria provided by the IJAS (2012) give clear connections between how well students apply the scientific method to their research and how their project is rated.

In 1999, the National Science Teachers Association (NSTA) adopted a position statement about science competitions (National Science Teachers Association, 1999, 2003). Additional commentary explaining the rationale for the NSTA position was provided by Bellipanni and Lilly (2003). The NSTA supports science fair participation as long as it is voluntary. The organization encourages schools to de-emphasize the competition aspect of science fairs and to make every effort to tie participation to other educational experiences. According to the NSTA, the overall emphasis of science fair projects should be to help students gain a general understanding of the scientific process, especially as it is applied to science content and application. The NSTA is also concerned that science fair projects be the work of the students. The organization would also like students to have opportunities for collaboration with scientists and science organizations. The NSTA position addresses common criticisms of science fairs and places the focus on student learning rather than on competition.

Two national science competitions that are open to high school students are the Intel Science Talent Search and the Google Science Fair. The Intel Science Talent Search
(formerly the Science Talent Search sponsored by Westinghouse) is a national science competition for high school students sponsored by a partnership between the Society for Science and the Public and Intel Corporation (Society for Science and the Public, 2014a). The competition is a venue at which students can present original research and gain recognition for their efforts from scientists and the public (Society for Science and the Public, 2012). However, the organization does not list specific learning goals for its participants.

The Google Science Fair is sponsored by Google; there are objectives and key outcomes for students who participate (Google Science Fair 2012, 2012). The objectives include helping students understand the scientific process and develop skills for inquiry, while the key outcomes focus on the ability of students to use the scientific method to perform an experiment and to use what they learn to suggest solutions to real-life problems. It should be noted that the Google Science Fair is not a science fair in the traditional sense, but is a virtual event to which the students submit their work online. The impact on student learning of participation in a virtual, as opposed to a live, event has not been studied.

The overall goal of these science fair competitions, whether stated explicitly or implied, is for students to learn about the scientific method by applying it to a project they choose. However, it is not clear how projects are rated in relationship to this goal, as the competitions’ criteria for judging projects are not given. The exception is the IJAS, as stated previously, whose judging criteria show a direct link between student application of the scientific method and the rating of the projects (Illinois Junior Academy of Science, 2012). There seems to be an underlying assumption to all of these competitions: if students participate in science fairs, the experience will increase their interest in science and make it more likely that they will pursue a science career. However, there is not a robust research
base to support this assumption. While there is some research to support the contention that interest in science will lead to pursuit of a science career (Archer, et al., 2010; Riegle-Crumb, Moore, & Ramos-Wada., 2011; R. D. Simpson et al., 1994), there is no research directly tying science fair participation to science interest or pursuit of science careers.

Understanding of the Scientific Process

It is commonly agreed that the purpose of a science fair should be to help students understand the scientific process (Bellipanni & Lilly, 2003). While this is a laudable goal, conducting a science fair project does not guarantee that such learning will occur. No studies directly linking science fair participation to increased student understanding of the scientific process were found when using search terms such as “science fair(s),” “science process,” and “science inquiry.” Sumrall and Schillinger (2004) listed recommendations to help ensure that true learning takes place during the implementation of a science fair program. In particular, they stated that teachers need to make concrete connections between the science fair and other curricular activities. Teachers also need to make sure that the students have a meaningful scientific rationale for what they are doing. The authors give an example of a student who baked biscuits with petroleum jelly instead of cooking oil as an example of a project that followed the scientific method but was of questionable scientific merit or worth (Sumrall & Schillinger, 2004). However, it could be argued that a science project that does not appear to have scientific merit or worth could still lead to significant student learning about science and the scientific process. The key is to have students work on something that is meaningful to them and be able to articulate that meaning, not just choose a random project.
from a book. Sumrall and Schillinger (2004) also stated that an often-overlooked benefit of science fair participation is development of writing, communication, and presentation skills.

The Illinois Junior Academy of Science criteria for judging science fair projects closely tie a high rating for a project to evidence of application of the scientific method (Illinois Junior Academy of Science, 2012). However, project ratings are by their nature a summative assessment of a student’s understanding of the scientific method and do not give an indication of the growth of the student’s understanding. It would be interesting to assess student growth in science understanding, not only as a result of doing a single science fair project but also over the course of several projects.

According to a survey conducted by Grote (1995), high school science department chairs are in general agreement with Sumrall and Schillinger (2004). Grote’s (1995) study found that most of the respondents believed that science projects were a valuable experience for students, promote enthusiasm about science, teach lessons that are not taught through other classroom activities, and give students experience developing communication skills. However, it was believed that science fair judging was counterproductive to the overall goals of science fairs and that while high school students benefited from independent research, the science fair format was more appropriate for middle school. Finally, because the survey respondents were high school science department chairpersons, they believed that teachers needed preservice and inservice training about effectively structuring independent student research (Grote, 1995). This observation agrees with the need that Sumrall and Schillinger (2004) saw for more careful crafting of the science fair experience in order to ensure that students achieve the intended learning outcomes. Very few science teachers have practical experience with scientific research, which could hamper their ability to help students design
and carry out science fair projects. Professional development that gives teachers experience with scientific research could enable them to be better guides for their students.

Science Olympiad

Science Olympiad competitions differ from science fair competitions because of their focus on team events in which students test their ability to use scientific instruments, to use what they know and have learned to solve problems, and to use their understanding of science content (Putz & Wirt, 2012), rather than being focused on research conducted by individual students. Science Olympiad explicitly states that the key goals of its program are to increase student understanding of the process of science inquiry and to encourage more students to pursue science careers (Science Olympiad, Inc., 2013).

Science Olympiad not only provides opportunities for local, regional, and national competitions; the activities can also be applied to individual classrooms (Cairns & Putz, 1990). Although Abernathy and Vineyard (2001) conducted a survey of Science Olympiad students, very few other studies have been done. O’Kennedy et al. (2005) reported positive student outcomes for the first Science Olympiad conducted in the European Union. A seminal work was a National Science Foundation-funded study conducted by McGee-Brown (2004) from 2000 to 2003 in 16 schools in Georgia. This wide-ranging study collected data from team coaches, school administrators, participants, parents, and Science Olympiad personnel in the form of personal interviews, focus groups, surveys (both open-ended and forced-response), and formal and informal observations. A consistent theme throughout the study results was collaboration. Parents, teachers, and students saw opportunities for
collaboration as the greatest strength of the program. Through participation in the program, students gained an understanding of the importance of science inquiry and found teamwork to be motivating and fun. Parents and teachers recognized that teamwork resulted in student pride in their accomplishments and positive recognition for their efforts. Students and parents also reported an increased enjoyment of science, improved problem-solving skills, improved group skills, and improved science achievement on the part of the students as a result of their participation (McGee-Brown, 2004).

McGee-Brown (2004) did not provide raw data to support the assertions in the study, except for the percentage of students who responded “yes” to the question about gender equity in science. In response to the question, “Has participation in Science Olympiad resulted in a view that both women and men can be equally competent scientists?” over the course of the 3-year study, an average of 85.3% of middle school males and 96.0% of middle school females responded “yes” (McGee-Brown, 2004, paragraph 9). Overall, she found that both middle school and high school students had increased their general enjoyment of science, that a majority reported enjoying their regular science classes more, and that some students had improved their science grades as a direct result of their participation in Science Olympiad. Students also indicated that they learned new science skills and content that they had not studied in their regular science classes (McGee-Brown, 2004).

McGee-Brown (2004) reported several obstacles to the implementation of Science Olympiad programs in schools. The major problem was scheduling. Because at most schools Science Olympiad is an extracurricular activity, it competes with many other activities for student time and attention. Other challenges are insufficient time and funds for materials, as well as the need for help in preparing students for events. Not mentioned by the
author was the challenge of funding travel to competitions. Many programs address these issues through parent and community volunteers and fundraising events. However, the majority of the people interviewed for the study thought that the program was of such high quality that it was well worth working to overcome these challenges to implement the program in their schools (McGee-Brown, 2004). Given the popularity and extent of Science Olympiad, further studies about the impact of the program on students and their learning are warranted.

Baird, Shaw, and McLarty (1996) investigated the relationship between student performance on tests of logical thinking and science-process skills and student success as Science Olympiad team members. They found some predictive value, but other factors such as the number of competitions a school attended, the type of school, the number of science courses completed, and the availability of computers in the school were also predictive. The authors ultimately did not recommend using tests to select Science Olympiad team members.

Wirt (2011) conducted a study of Science Olympiad competitors’ attitudes and perceptions toward their participation through an analysis of survey data collected by the organization. The survey was conducted through a website that the participants logged into, and the data was disaggregated as being from a student, college student, or adult. The survey provided the opportunity for open responses. Wirt was unable to show a statistically significant effect in her quantitative analysis. However, her qualitative data showed that most participants perceived a positive benefit from their participation and that their participation influenced their choice of careers. However, her subjects were self-selected, in that they logged into the website, and she was unable to disaggregate the data by age of student. She
suggested that further research be conducted that compares presurveys and postsurveys as well as compares science fairs to Science Olympiad.

Science Fair, Science Olympiad, and the Middle School Philosophy

In 1982, the Association for Middle Level Education (AMLE) first published This We Believe, a position paper that outlines the importance, goals, and essential attributes and characteristics of effective middle-level education (Association for Middle Level Education, 2014). The document is now in its 4th edition (Association for Middle Level Education, 2010, 2014). Children between the ages of 10 and 15 undergo rapid and intense physical and intellectual changes that merit an educational approach that is tailored to their specific needs. In addition, these children need to be prepared to function in an increasingly complex world where they will need to be able to solve complex problems individually and collaboratively (Association for Middle Level Education, 2010). According to the AMLE (2010), some of the goals of an effective educational program for young adolescents are: asking questions and confronting big ideas for which there may not be one right answer, using rational- and critical-thinking skills, accessing information from a variety of sources and assessing and interpreting that information, understanding and engaging in the process of inquiry, and developing the social skills to effectively work with others. In This We Believe (2010), the Association for Middle Level Education delineates 16 characteristics of an effective middle-level education program. A summary of these characteristics as they relate to science fairs and Science Olympiad is found in Table 1 (Association for Middle Level Education, 2010, p. 14). Seven of these characteristics apply directly to science fairs and Science Olympiad. In
the category of “Curriculum, Instruction, and Assessment” (Association for Middle Level Education, 2010, p. 14) the four characteristics of active and purposeful learning, a challenging/exploratory/integrative/relevant curriculum, multiple learning and teaching approaches, and varied and meaningful assessments are exemplified by both science fairs and Science Olympiad.

These goals are very similar to the goals of the Illinois Junior Academy of Science (2012) which emphasize the importance of critical thinking and systematic investigation in the successful completion of a science fair project. The National Science Teachers Association position (National Science Teachers Association, 1999, 2003) on science fair participation focuses on student understanding of the scientific process, which also supports the AMLE (2010) goal of understanding of the inquiry process. To successfully complete a science fair project, students need to choose a question that can be investigated, but may not have one correct answer. In addition, the students need to access and evaluate information from a variety of sources, not only print and electronic, but also their own investigations and experiments, and perhaps experts in their field as well (Illinois Junior Academy of Science, 2012). The process of choosing a question and finding a possible answer fits well with the goals of the Association for Middle Level Education (2010). Science Olympiad also fits the Association for Middle Level Education (2010) goals well in terms of critical thinking and information gathering, with the additional benefit of helping students develop social skills; the team aspect of Science Olympiad competitions helps students develop collaboration skills (Science Olympiad, Inc., 2013).
Table 1

*Correlations Between the Association for Middle Level Education’s (AMLE) 16 Characteristics of Successful Schools for Young Adolescents and Science Fair and Science Olympiad*

<table>
<thead>
<tr>
<th>AMLE characteristic</th>
<th>Science fair</th>
<th>Science Olympiad</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Curriculum, Instruction, and Assessment:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Educators value young adolescents and are prepared to teach them</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Students and teachers are engaged in active, purposeful learning</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Curriculum is challenging, exploratory, integrative, and relevant</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Educators use multiple learning and teaching approaches</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Varied and ongoing assessments advance learning as well as measure it</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Leadership and Organization:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A shared vision developed by all stakeholders guides every decision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaders are committed to and knowledgeable about this age group, educational research, and best practices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaders demonstrate courage and collaboration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ongoing professional development reflects best educational practices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organizational structures foster purposeful learning and meaningful relationships</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Culture and Community:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The school environment is inviting, safe, inclusive, and supportive of all</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Every student’s academic and personal development is guided by an adult advocate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comprehensive guidance and support services meet the needs of young adolescents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health and wellness are supported in the curricula, school-wide programs, and related policies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The school actively involves families in the education of their children</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>The school includes community and business partners</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>


In science fairs, the students are active participants in their learning through choosing the questions they want to investigate and in choosing the methods of their investigation (Illinois Junior Academy of Science, 2012). In Science Olympiad, the students are active in meeting the challenges of each of the events in which they participate (Science Olympiad,
Both types of competition are very purposeful in that they have an end-goal in mind: preparing for a successful competition. Both types of competition can be tailored to student needs for challenge, exploration, integration, and relevance through student choice of project (science fairs) or event (Science Olympiad). For example, in my experience as a middle school teacher, a common science fair project is an investigation of which laundry detergent is the most effective. Such a project can be as narrow as surveying people about their laundry detergent preference or as wide as encompassing the chemistry, economics, and environmental impacts of detergents. Science Olympiad has this flexibility as well through the wide variety of topics and formats of its events. For example, the 2014 event roster includes events in which students build helicopters, create topographic maps, interpret astronomical data, and use their knowledge of human anatomy (Science Olympiad, Inc., 2013). Teachers can find multiple ways to assess learning throughout both types of competition.

The three characteristics of a middle-level program that relate to and correlate with science competitions are guidance by an adult advocate, involving families, and partnerships with the community and businesses. The discussion of adult advocates in This We Believe (Association for Middle Level Education, 2010) is focused on adults as advisors in either a formal or informal advocacy program. However, an adult can also serve as an advocate for a student in the context of a science fair or Science Olympiad. The amount of individualization that is possible in a science fair program lends itself well to a model in which adults can serve as mentors for students. These mentors could be the classroom teacher, other school personnel, family members, or outside experts. Science Olympiad coaches also have the opportunity to become mentors and advocates for their students. Involvement of family
members is a key to the success of both science fairs and Science Olympiad (Illinois Junior Academy of Science, 2012; Science Olympiad, Inc., 2013). For both types of competition, family members not only work with their own children in preparing for competition, but they also are needed to serve as event organizers and helpers, fundraisers, and judges. Finally, community and business partners can be instrumental in providing funding and other support for the competitions, including being mentors for students.

The *National Science Education Standards* (National Research Council, 1996) and the Next Generation Science Standards (NGSS Lead States, 2013) contain components that correlate well with the best practices for middle schools as expressed by the AMLE (2010) and the goals of science fairs (Illinois Junior Academy of Science, 2012) and Science Olympiad (Science Olympiad, Inc., 2013). These include inquiry based on student-generated authentic questions; curricula based on interests, abilities, and life experiences of students; making connections with outside resources; allowing students to have a voice in what and how they will learn; and creating an environment where students are encouraged to collaborate (National Research Council, 1996). The National Science Teachers Association in *Pathways to the Science Standards: Middle School Edition* (Rakow, 1998) expanded on these ideas by emphasizing the importance of individualizing instruction to meet student needs, opportunities for students to actively engage in extended inquiry with adult guidance, and student use of inquiry processes. R. Allen (2007) agreed with these positions and added emphasis on the importance of giving students time to think and frequent occasions to write about their thinking in order to improve their critical-thinking skills. Expressing thoughts clearly is an essential component of both science fair (Illinois Junior Academy of Science,
Science fair and Science Olympiad participation can meet several needs of young adolescents, both academically and socially. Both types of competition provide a very flexible framework within which individual student interests, need for challenge, and growth in inquiry skills and critical thinking can be accommodated. In addition, valuable connections with family members and other adults can be made. The goals of science fairs and Science Olympiad are compatible with an effective middle-level education program.

Competition and Motivation

One of the more controversial aspects of science fair participation for educators and parents is whether to emphasize the competition portion of the process. Schools are encouraged by the NSTA (National Science Teachers Association, 1999, 2003) to de-emphasize the competition portion of a science fair. Abernathy and Vineyard (2001) conducted an extensive study of participants in the state science fair and Science Olympiad in Utah and their attitudes toward the competition aspects of these programs. For both groups, the students chose science competitions as their first choice for an academic competition, followed by music competitions. Other choices were geography fair, history fair, math contest, speech/debate, foreign language fair, academic decathlon, read-a-thon, and art contest. When asked about what they found rewarding about participating, students from both types of competition ranked fun and learning new things as their top choices. For science fair participants, competing against other students, learning the scientific process, and
sharing ideas with others rounded out the top five. Though the NSTA position is that science fair participation should be voluntary (National Science Teachers Association, 1999, 2003), Abernathy and Vineyard (2001) found that for many students, science fair participation was mandatory, whereas it was more common for Science Olympiad to be voluntary. The authors (Abernathy & Vineyard, 2001) state that while required participation in science fairs may not be recommended by the NSTA, teachers may have good curricular reasons for requiring it. Science fair participation is an opportunity for students to engage in the scientific process with teacher assistance, so the authors state that “what may appear to be coercion may really be an opportunity” (Abernathy & Vineyard, 2001, p. 274). Abernathy and Vineyard (2001) also question whether, given adolescent developmental stages, it is reasonable to expect a student to participate in such a time-consuming and sometimes difficult enterprise without some sort of external motivation. They disagree with the findings of Czerniak and Lumpe (1996) about the damaging effects of classroom competition. The students in their sample found the events to be fun, and valued the competition aspects, therefore, Abernathy and Vineyard (2001) see a need for further research on the effects of extracurricular competition on student motivation. It is possible that the discrepancy between the results of these studies is related to the way that the respective competitions were structured. For example, the amount of classroom time allotted to the project, the level of teacher guidance and parental involvement, and the criteria for assigning grades could all affect the attitudes of the students toward an event. These factors vary widely from school to school and teacher to teacher, making it difficult to form reliable comparisons.

Czerniak and Lumpe (1996) and Czerniak (1996) applied cognitive theories of motivation in order to study the motivations of science fair participants, and Czerniak and
Lumpe (1996) studied factors that influence participation in science fairs. They were most interested in students’ attitude toward participation (including possible approval or disapproval from parents, teachers, and others) and the perceived behavioral control involved in their participation. When the students were surveyed about their beliefs, the most common advantages listed were the opportunity to learn something and to receive extra credit or improve a grade, while the most common disadvantages were wasted time on the weekends and hard work (as defined by the students; see Table 2).

### Table 2

*Student Beliefs About Science Fair Participation*

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opportunity to learn something</td>
<td>Wasted time, especially weekends</td>
</tr>
<tr>
<td>Extra credit/improve grade</td>
<td>Hard work</td>
</tr>
<tr>
<td>Money or prizes</td>
<td>Nervousness</td>
</tr>
<tr>
<td>Having a good experience</td>
<td>Presenting in front of people</td>
</tr>
<tr>
<td>Impact on academic record</td>
<td>Affecting grades</td>
</tr>
<tr>
<td>Improving presentation skills</td>
<td>Possibility of failure</td>
</tr>
<tr>
<td>Meeting new people</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>54%</td>
<td>61%</td>
</tr>
<tr>
<td>28%</td>
<td>20%</td>
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<tr>
<td>23%</td>
<td>15%</td>
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<tr>
<td>16%</td>
<td>9%</td>
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<td>14%</td>
<td>8%</td>
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<tr>
<td>13%</td>
<td>8%</td>
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<tr>
<td>10%</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Adapted from Czerniak and Lumpe (1996).

Students listed teachers and parents as approving of their participation (66% and 58%, respectively), and a small minority listed friends, siblings, and other teachers as disapproving of their participation. The science fair was a mandatory activity for 81% of the students and counted toward the grade in science class for 77% of the students. Moreover, 70% of the participants had parents who had more than a high school education. The authors concluded that science fair participation was statistically more likely if it was required for a class, which
is hardly surprising, given that 81% of the students present were required by their school to attend. The authors noted that the NSTA position is that science fair participation should be voluntary and that best practice for middle school-aged students is generally believed to consist of noncompetitive co-operative learning activities (National Science Teachers Association, 1999). The authors were very concerned about the level of coercion involved in mandatory science fair participation and questioned whether the benefits claimed for science fairs (such as developing science skills) were worth the possible psychological harm that participation may cause students (Czerniak & Lumpe, 1996). It might be reasonable for teachers to consider alternatives to having students complete projects on their own outside of class, in order to mitigate the main objection of “wasted time, especially on weekends.” Teacher support could also be valuable for helping the relatively small percentage of students suffering from anxiety and fear of failure. While some of the advantages of participation are extrinsic motivators (grades, prizes), there are enough intrinsic advantages to participation (learning, presentations skills, meeting people) noted by the participants that it is worthwhile to address the main disadvantage (“wasted time, especially on weekends”) in order to make the experience more enjoyable for students, rather than not offer science fair participation at all.

In a companion study, Czerniak (1996) studied the traits of students relating to their success in a regional science fair. The main finding of this study was that the overriding factor regarding success was the pressure to succeed. This included parental pressure to succeed academically (which also included parental help with the project and with time management), and the contribution that the science fair project, and in some cases, the judges’ rating, made toward their grade. Judges and teachers interviewed by the author
questioned parent participation in their child’s projects, because it was often difficult to discern how much work was actually performed by the student. The author also pointed out that having the judges’ scores count toward their grade caused significant anxiety for some students. Czerniak (1996) raised issues about the effect of poor performance at a science fair on a student’s self-concept and attitude toward scientific research. Czerniak (1996) listed sample survey questions and statistical data (structure coefficients and discriminant functions) but not the complete list of survey questions or raw data. What about the ethics of having the ratings given by science fair judges count toward a student’s grade? Science fair judges are volunteers and vary greatly in their subject expertise as well as in their ability to fairly evaluate student work. Therefore, the playing field is not level. While it can be argued that receiving feedback on their work by an outside person is valuable for students in order for them to gain another perspective about their work and improve their presentation skills, it needs to be done in a way that will result in a positive experience for the students. However, some would argue that even a negative experience can help students build persistence and grit. Goodwin and Miller (2013) argue that the research supports helping students to embrace challenge, to set and achieve goals, to exercise self-control in avoiding distractions, and to see failure as an opportunity to improve.

In a retrospective study of science competition involvement, Forrester (2010) surveyed and interviewed college freshmen about the role of science competition involvement in their choice of a major. Freshmen who had participated in science competitions were more likely to pursue engineering majors and had a greater sense of self-efficacy in science. However, they also reported that the encouragement and support of parents, teachers, and peers were also pivotal in their decision to pursue a science or engineering career.
A goal of science competitions is increasing student interest in science and perhaps thereby increasing the number of students who pursue science as a career. Encouraging students to engage in science/technology/engineering/mathematics (STEM) education and careers is a topic of much interest to educators, the government, and the public as evidenced by the existence of organizations such as the STEM Education Coalition whose members include educational organizations, such as the National Science Teachers Association and the Illinois Mathematics and Science Academy, business groups such as the National Association of Manufacturers, and public service groups such as the Campaign for Environmental Literacy (STEM Education Coalition, 2012). Even a cursory examination of the literature about STEM education very quickly uncovers many examples of programs for all ages. Some examples include strategies for teaching STEM to students in Grades K-4 (Perrin, 2004; Swift & Watkins, 2004), using robotics to motivate elementary school students (Rogers & Portsmore, 2004), and outreach to rural students (Matson, DeLoach, & Pauly, 2004). However, these programs (and most others) do not include a data-collection component for student attitudes and content knowledge, so it is impossible to objectively determine if these programs achieved their goals.

A few of the studies that assess student knowledge and attitudes following involvement in STEM education activities exists for high school programs. Zhe, Doverspike, Zhao, Lam, and Manzemer (2010) studied a high school summer program designed to encourage students to consider pursuing STEM majors in college. Students engaged in research with a faculty member and a graduate student mentor. After the program, students were debriefed in focus
groups. Of the students opting to attend college, 86% indicated that they would choose a STEM major, and many cited their participation in the program as a contributing factor. The students found that the confidence in their abilities that they gained as well as the exposure to problem-solving research were the deciding factors in their decision. Two studies assessed the impact of project and problem-based learning on student career aspirations. Kanter (2010) found that increased teacher science-content knowledge and a problem-based learning approach increased student achievement but not student attitudes toward science and science careers. However, increasing the frequency of hands-on inquiry-type activities in class improved the students’ attitudes. Mioduser and Betzer (2007) found that a problem-based learning approach did significantly improve attitudes toward technology and technology studies at the Israeli high school they studied. While these studies do not specifically address science fairs, exposure to research, hands-on activities, a problem-based approach to learning, and opportunities for mentoring are all common components of science fair projects.

A few studies have been conducted regarding factors that influence a student’s self-image as a scientist. Aschbacher, Li, and Roth (2010) studied 33 students through longitudinal surveys and interviews to assess their changing attitudes toward pursuing a STEM career. They categorized the students as “high-achieving persisters,” “low achieving persisters,” and “lost potentials” based on student achievement, “science identity,” and participation in science (Aschbacher et al., 2010, p. 567). The main differences between the groups that persisted and those that did not were experiencing success in science and support from people who were important to the students. The authors noted that most of the students did not have advocates at home or school and that there was a pressing need for these students to interact with scientists and other role models. Hazari et al. (2010) conducted a
similar study of high school students and their physics identity. The data were collected from surveys conducted as part of the Persistence Research in Science and Engineering project (Harvard-Smithsonian Center for Astrophysics, n.d.). The Hazari, et al. (2010) found that students who opted to pursue a career in physics often credited participation in classes that focused on real-world connections, conceptual understanding, and class discussion. However, the main factor in their career decisions was often the encouragement of a supportive teacher. While this finding minimizes the impact of science competitions in encouraging students to study science, such competitions sometimes provide an environment where such individual support and encouragement can occur.

A few studies have been conducted about children’s attitudes toward science careers. Archer, et al. (2010) conducted a study in England about the attitudes of 10- and 11-year-olds toward science and scientists. The researchers focused on data collected through focus group discussions that were the initial phase of a 5-year longitudinal study. Archer, et al. (2010) found that the children were enthusiastic about doing science but did not want to become scientists because they perceived it as being hard, dangerous, masculine, and that scientists were “boffin” (the British equivalent of a geek or nerd). Riegle-Crumb et al. (2011) studied eighth-grade students who were part of the 2003 Trends in International Math and Science Study (TIMSS) cohort. They found a decrease in enjoyment of science from fourth to eighth grade but found that enjoyment of science was not a strong indicator of science achievement. However, enjoyment of science was a strong indicator of career aspirations in science. The researchers found that White and Hispanic females were about half as likely as White males to aspire to a math career, but no consistent patterns were found in their aspirations to science careers. Black and Hispanic males aspired to math and/or science careers at about the same
rate as White males but had much lower academic achievement. This disconnection between science achievement, science enjoyment, and career aspiration is intriguing; just because a student learns science content does not mean that he or she will love science, or vice versa. Is it possible that science competition participation could help to close this gap?

R. D. Simpson et al. (1994), in a review article, defined the affective domain of science education in terms of attitudes, values, beliefs, and motivation. In the section about science careers, the authors use the metaphor of a STEM career pipeline, in which students leak out of the pipeline through their choices of courses in high school. Key factors in keeping the students in the pipeline and eventually entering a science career were identified as pursuing science hobbies as a child and parent/teacher/peer encouragement. In a similar study in England, Anna Cleaves (2005) investigated the factors that influenced whether students pursued science courses at the secondary and postsecondary level. The data were collected from 72 high school students through four interviews conducted over 3 years. She found two key factor: students were unaware of what scientists do and a lack of confidence in their ability to study science successfully. Mau (2003) used data from the National Educational Longitudinal Study that were collected from 1988 to 1997 to investigate student career aspirations in relation to gender and race. Female and minority students who were confident in their ability to achieve in science were more likely to persist in pursuing science and engineering careers. From these studies, it it can be concluded that while science achievement is important for keeping students in the STEM career pipeline, student attitudes are of the utmost importance. Barriers to helping students develop a positive attitude toward science study are lack of exposure to what scientists and engineers actually do and little confidence in their ability to be successful in science. Science competition participation
could break down both of these barriers by enabling students to experience science as a practitioner in a format in which they can be successful.

Maltese and Tai (2010) studied the transition that takes place when a student becomes a professional scientist by interviewing graduate students, practicing scientists, and retired scientists about their early experiences in science. A majority of the study participants indicated that they became interested in a science career before middle school, and 40% indicated that their initial experience with science was school-related (including science fairs and science camps). However, when analyzed by gender, 33% of the males found their initial interest in science through a school-related activity, in contrast to 52% for the females. In addition, females generally attributed their early interest to school or family factors, while males credited personal curiosity for their interest in science. The importance of teachers who encouraged and nurtured students was a universal theme. Maltese and Tai (2010) concluded from their study that if the goal is to increase the number of students who persist in science, the commonly used interventions, that aim at increasing student enrollment in secondary-level coursework, or that target increasing student achievement in science will not be very effective. This finding correlates with the disparity between science enjoyment and science achievement that was found by Riegle-Crumb et al. (2011). Based on their interviews (Riegle-Crumb et al., 2011), providing early science experiences with a range of content areas and multiple modes of learning in engaging classrooms with supportive teachers is a better use of scarce resources. Science fairs would fit this model, with their emphasis on student interest in selection of their projects.

Overall, based on the research, the key factors that contribute to student interest in pursuing STEM education and careers are enjoyment of scientific pursuits and strong adult
support, whether through parents, teachers, or mentors. Barriers are student lack of
knowledge about science careers, lack of confidence in their ability to successfully study
science, and little exposure to engaging science instruction at an early age. Students who
experience success in science, especially through hands-on experimentation in a problem-

based environment with real-world connections, are the most likely to enjoy science. These
factors are summarized in Table 3.

Table 3

<table>
<thead>
<tr>
<th>Positive influences</th>
<th>Barriers</th>
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<tbody>
<tr>
<td>Enjoyment of science</td>
<td>Lack of confidence</td>
</tr>
<tr>
<td>Strong adult support</td>
<td>Lack of knowledge about science careers</td>
</tr>
<tr>
<td>Hands on experimentation with real world connections</td>
<td>Lack of engaging science instruction at an early age</td>
</tr>
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</table>

Science competition participation, with its opportunities for students to choose their
investigations and to have individualized adult support, fits very well with this model.
However, whether science fair participation leads to greater student interest in pursuing
STEM careers has not been studied; none of the studies about factors that lead students to
pursue STEM careers mentioned science fair participation.
Measuring Attitudes Toward Science

Over the last 40 years, several science attitude inventories have been used to assess student interest in science education and careers. Examples of inventories used with middle school-aged students are the Test of Science Related Attitudes (TOSRA; Fraser, 1981), the revised Science Attitude Inventory (SAI II; Moore & Foy, 1997), and the Science Opinion Survey (SOS; Gibson & Chase, 2002; O’Sullivan & Weiss, 1999).

The Test of Science Related Attitudes battery consists of 70 statements that a student rates on a 5-point scale, ranging from strongly agree to strongly disagree. The statements are divided into seven scales that are designed to measure student interest in and enjoyment of science activities as well as interest in science careers (Fraser, 1981). The TOSRA battery field-test group included 1,337 students in levels 7-10 (ages 12-16) at 11 schools in the Sydney, Australia metropolitan area. The author found the internal consistency reliability as measured by the Cronbach alpha coefficient to be very high (0.82, 0.80, 0.81, 0.84 for levels 7 through 10, respectively (Fraser, 1981). Test retest reliability was also very high, with a coefficient of 0.78 (Fraser, 1981). The author assessed the validity of the test by comparing the intercorrelation of the scales within the TOSRA to each other. The average was a relatively low 0.33, but the author felt justified in keeping all seven scales (Fraser, 1981).

The SAI II is a revision of the original Science Attitude Inventory that was developed in 1970 (Moore & Sutman, 1970). The revisions made to the original inventory focused on rewording statements to remove gender bias, changing the wording of questions that researchers had found to be difficult for the students to understand, and reducing the number of questions (Moore & Foy, 1997). The SAI II is based on 12 position statements that are
worded both positively and negatively, for a total of 40 attitude statements that the students rate on a Likert-type scale of 1-5. The authors claimed construct validity based on the original SAI, and the validity of the revised instrument was evaluated via a field test of 588 students in the sixth, ninth, and 12th grades. Moore and Foy (1997) determined that the inventory was valid based on $t$-test results showing that the total score, as well as the scores on the subscales, accurately differentiate students with positive attitudes from those with more negative attitudes. In addition, they found the inventory to be reliable based on Cronbach’s alpha of 0.781 (Moore & Foy, 1997).

The Science Opinion Survey was used by Gibson and Chase (2002) to evaluate middle school students who participated in Summer Science Explorers, a 2-week science camp held at a college campus. The Gibson and Chase (2002) stated that the assessment was first developed in the late 1980s by the National Assessment of Educational Progress (NAEP); however, in spite of extensive searching, the researcher was unable to find the original survey, and Gibson and Chase (2002) did not provide a reference. Eight questions from the original survey were adapted and included in the 1996 NAEP assessment, as described by O’ Sullivan and Weiss (1999). According to the NAEP website (National Center for Education Statistics, 2012b), science attitude questions are no longer a part of the assessment. The version of the Science Opinion Survey used by Gibson and Chase (2002) consists of 30 questions, 16 of which are stated positively (such as “Science lessons are fun”), and the remainder are stated negatively (such as “Science lessons bore me”; Gibson, 2008). The students respond by using a 5-point Likert-type scale ranging from strongly agree to strongly disagree, and the responses are scored from -2 to +2, with a positive score indicating a positive attitude toward science (Gibson, 2008; Gibson & Chase, 2002). Gibson and Chase
(2002) did not give validity and reliability data for the survey instrument. However, they did find statistically significant differences when they performed a cross-sectional analysis of their groups using a factorial ANOVA design and differences within groups when analyzed longitudinally using a mixed-factorial ANOVA (Gibson & Chase, 2002).

Defining and Assessing Science Inquiry Skills

In 1996, the National Research Council published the *National Science Education Standards* in which they defined science inquiry as

a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories. (p. 214)

In a follow-up publication, *Inquiry and the National Science Standards* (National Research Council, 2000), the National Research Council gives an example of how a scientist uses the process of science inquiry in his or her work and how this process can be transferred to the classroom. In summary, the NRC (2000) definition of the science inquiry process is:

curiosity about an observed phenomenon, defining questions using background knowledge, proposing an explanation or hypothesis as a starting point, planning and conducting investigations; gathering data, analyzing data and constructing an explanation that also takes into account other possible explanations, communicating results and testing the explanation. This definition of the science inquiry process is supported by other authors, such as Anderson (2007) and Yager (2009), and follows closely the recommended procedure for developing and carrying out a science fair project (Illinois Junior Academy of Science, 2012).
The Next Generation Science Standards (NGSS Lead States, 2013) are based on *A Framework for K-12 Science Education* (National Research Council, 2012). Rather than referring to science inquiry, this document outlines several science and engineering practices as one of the dimensions of the framework, along with crosscutting concepts, and disciplinary core ideas (National Research Council, 2012, p. 3). These science and engineering practices are substantially the same as the steps of the inquiry process as defined by the NRC in 2000, in that they include asking scientific questions, planning and conducting investigations, analyzing and interpreting data, and communicating results (National Research Council, 2012). In addition, the framework explicitly delineates several inquiry processes that are embedded (but not delineated) in the earlier definitions, such as developing and using models, using mathematics and computational thinking, and engaging in argument from evidence” (National Research Council, 2012, pp. 50-53). Overall, the scientific and engineering practices in the framework (National Research Council, 2012) offer an expanded definition with more detailed explanations of the science inquiry process than were described in earlier publications by the NRC (National Research Council, 1996, 2000) without calling the process “science inquiry.”

Based on the definitions of science inquiry given by the NRC (1996, 2000) and other authors (Anderson, 2007; Yager, 2009), effective assessment of student understanding of the science- inquiry process should include student ability to formulate scientifically testable questions, plan and carry out investigations, collect and analyze data, and construct explanations based on evidence. Ideally, such assessments should include not only paper and pencil tests but should also encompass projects, research reports, lab notebooks/journals, portfolios, and extended essays (National Research Council, 2000). Any of these assessment
techniques could be used formatively or summatively. Student-generated rubrics and peer/self-evaluation could also play a role (Pinner, 2009). However, in common practice, science assessments at the national, state, and classroom level are summative, using a multiple-choice paper and pencil format (National Research Council, 2012). According to the NRC (2012), such assessments are necessarily limited to providing information about student understanding of conceptual information, although with better design is it possible to glean some information about other science practices.

Two national assessments of student learning are the National Assessment of Educational Progress and Trends in International Mathematics and Science Study (National Center for Education Statistics, 2012b, 2012d). The NCES has made sample questions from past examinations available that are searchable by subject matter, grade, difficulty, and type of question. The researcher’s search of the database of eighth-grade questions for questions categorized as science inquiry or science investigation yielded an average of three questions per year for the 2000, 2005, 2009, and 2011 examinations. These questions were either short or extended constructed-response and were graded with a rubric. The Trends in International Mathematics and Science Study (TIMSS) is administered to fourth- and eighth-grade students in over 60 countries (National Center for Education Statistics, 2012d). Assessment questions are available for the 1999 and 2005 TIMSS examinations (National Center for Education Statistics, 2012c). The 1999 TIMSS examination for eighth-grade included four multiple-choice questions that were classified as scientific inquiry and the nature of science (National Center for Education Statistics, 2012c). The 2005 TIMSS examination for eighth-grade had no questions in this category (National Center for Education Statistics, 2012c). Even though science inquiry questions appear on these national and international assessments, given the
small number of questions, assessing science inquiry-skills is not a major, or even a minor, focus of the NAEP and TIMSS.

Some researchers have constructed written assessments of student-inquiry skills. The Discovery Inquiry Test (DIT) was used by Kahle, Meece, and Scantlebury (2000); Johnson, Kahle, and Fargo 2006; and Johnson, Zhang, and Kahle (2012) in studies of middle school teacher effectiveness and student achievement. The DIT consists of 29 questions drawn from the NAEP’s questions from 1990 and 1992. Four of the questions were categorized as nature of science; the others focused on life, earth/space, and/or physical science. The questions were chosen for their emphasis on conceptual understanding and science processes, rather than vocabulary and facts. The reliability of the DIT was given as a Cronbach’s alpha of 0.94.

Wenning (2007b) developed the Science Inquiry Literacy Test (ScInqLiT, based on his definition of the stages of scientific inquiry, that are, on sum, very similar to the definition of science inquiry given by the NRC (1996, 2000). His additions to the general definition are applying numerical and statistical methods to data, and explaining unexpected results. The ScInqLiT examination is a 35-item multiple-choice test that assesses the ability of high school students to design scientific investigations using the principles of scientific inquiry. The test was found to be reliable and valid. The ScInqLiT assessment has been used as part of the Student Teacher Effectiveness Reporting System at Illinois State University (Wenning, 2007a).

The NRC has recognized that there is a need for students to be proficient in the process of scientific inquiry (National Research Council, 1996, 2000) and science and engineering practices (National Research Council, 2012). However, assessment of these skills is limited
on national and international tests (National Center for Education Statistics, 2012a, 2012b, 2012c, 2012d). There are also very few research based assessments available that can be used at the classroom level.

Conclusion

Science competitions are a familiar feature of the educational landscape, but their effects on student learning and career aspirations have not been well studied. The goals of science competitions, whether explicitly stated or merely implied, are to help students learn the scientific method through application and to increase student interest in science and science careers. The goals of these competitions correlate with the characteristics of successful middle level education programs as defined by the Association for Middle Level Education (2010). While the attainment of these goals has not been well studied, other research exists that can inform future studies in this area. The research in STEM education suggests that student enjoyment and adult support contributes to student enthusiasm for pursuing a STEM career. The researchers who studied student motivation and attitudes relating to science fair competitions (Abernathy & Vineyard, 2001; Czerniak, 1996; Czerniak & Lumpe, 1996) disagreed about how motivating the competitions are for students. The research on student motivation and attitudes relating to Science Olympiad competitions is more positive, especially as it relates to collaboration (Abernathy & Vineyard, 2001; McGee-Brown, 2004; Wirt, 2011). If enjoyment of science is a key component of a decision to pursue a science career, further research into which aspects of science competitions lead to student enjoyment is merited. Perhaps the most glaring gap in the research is whether students achieve one of the primary
goals of science competition participation: improving science inquiry understanding. Methods for measuring this goal are sorely needed in order to justify the time and attention devoted to science competitions.
CHAPTER 3

METHODOLOGY

Little is known about the effect of formal science competition participation by middle school students on their attitudes toward STEM coursework and careers. Even less is known about the effects of these competitions on the students’ science inquiry understanding and skills. The purpose of this study was to fill this gap by determining whether middle school students changed their attitudes toward STEM coursework and/or careers and increased their understanding of scientific inquiry as a result of participating in science fair and Science Olympiad competitions. This chapter includes a description of the procedures for data collection, the methods of data analysis, and the rationale for choosing these procedures and methods.

Research Questions

1. Does formal science competition participation in middle school promote an increase in the understanding of science inquiry?

2. Does formal science competition participation increase middle school student interest in studying STEM subjects and pursuing STEM careers?
3. Are there differences in the understanding of science inquiry among middle school students who participated in science fairs and those who participated in Science Olympiad?

4. Are there differences in attitudes toward STEM subjects and careers among middle school students who participated in science fairs and those who participated in Science Olympiad?

Research Design

The study was approved by the Northern Illinois University Office of Research Compliance and Integrity (Northern Illinois University Office of Research Compliance and Integrity; Appendix A). In addition, the researcher completed the CITI Basic Course in the Protection of Human Research Subjects through the University of Miami (Appendix B). The study design was sequential mixed-method as described by Creswell (2008). This design was chosen because the focus of the study was the collection of quantitative data followed by the collection of qualitative data. Mixing quantitative and qualitative methods is a pragmatic approach to research, in which the research questions themselves are the focus rather than the method of data collection, and multiple methods of data collection are employed to answer them. Collecting both quantitative and qualitative data allowed for triangulation of the data, whereby the results from the quantitative portion of the study were followed by a more thorough qualitative investigation (Creswell, 2008). See Table 4 for a summary of the data collection methods that were employed to address each research question.
Table 4
Research Data Collection Methods

<table>
<thead>
<tr>
<th>Research question addressed</th>
<th>Data collection method #1: Pre and post -- Science Opinion Survey</th>
<th>Data collection method #2: Pre and post Middle School Science Inquiry Literacy Test</th>
<th>Data collection method #3: Focus groups</th>
</tr>
</thead>
<tbody>
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<td>X</td>
<td></td>
</tr>
<tr>
<td>Research question #2: Does formal science competition increase middle school student interest in studying STEM subjects and pursuing STEM careers?</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Research question #3: Are there differences in understanding of science inquiry between middle school students who participated in science fairs those who participated in Science Olympiad?</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Research question #4: Are there differences in attitudes toward STEM subjects and careers between middle school students who participated in science fairs those who participated in Science Olympiad?</td>
<td>X</td>
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The design was quasi-experimental, as students were maintained in intact classroom groups (Wiersma & Jurs, 2005). Campbell and Stanley (1963) refer to this quasi-experimental design as “the nonequivalent control group design” (p. 47) because it is not possible to randomly assign students to control and treatment groups. Mertens (2010) describes this model as a one-group pretest-posttest design. While this design may be weakened by validity concerns, it is justified in this case because of the necessity of using intact classroom groups (Mertens, 2010).

Subjects

Science Olympiad competitions are open to students in Grades K-12 (Science Olympiad, Inc., 2013). However, the youngest age at which students can compete in science fairs sponsored by the Illinois Junior Academy of Science (Illinois Junior Academy of Science, 2012) is seventh-grade. Therefore, seventh grade students of both genders were the subjects for this study in order to investigate the attitudes and skills of the students with the least experience in science competitions.

For the quantitative portion of this study, the subjects were 86 students in eight intact classroom groups or Science Olympiad teams. Science Olympiad teams from five schools and three schools with science fair programs participated. Within each intact classroom and Science Olympiad team, all of the students should have received the same regular science instruction, so any effects on science attitudes and skills should have been the same for all of the students within that group. For the qualitative portion of the study, one to three focus groups of four to 13 students each from each classroom or Science Olympiad team were
interviewed. At many schools, Science Olympiad is an extracurricular team activity (Science Olympiad, Inc., 2013). For the purposes of this study, a school’s Science Olympiad team was treated as an intact classroom, even though its students were drawn from several classes (see the Limitations section under Quantitative Data Analysis for further discussion).

The research participants were drawn from schools participating in the IJAS science fairs and Science Olympiad in Illinois. A list of participating schools was obtained from each organization i.e. the IJAS and Science Olympiad. E-mails were sent to the sponsoring teachers and their principals at 100 schools in Illinois described the project and invited them to contact the researcher for more information. From this pool, 14 schools replied to the invitation with requests for more information. The researcher replied to their requests for information through e-mail, phone conversations, and meetings. Eight schools, three with science fair programs and five with Science Olympiad teams, agreed to participate in the project.

The researcher worked with the teachers to obtain permission to participate in the study from school district officials, according to the policies of the individual district. All participating teachers and principals signed permission forms required by the Northern Illinois University Office of Research Compliance and Integrity rules (Appendix C). Participating students were required to have parental permission to take the written assessments and participate in the focus groups in compliance with school district policies and the Northern Illinois University Office or Research Compliance and Integrity rules (Appendix C). All students were also required to sign assent forms (Appendix C). The classroom teachers collected the parental permission forms and student assent forms and
were instructed to copy the forms so that both the classroom teacher and the researcher had a set of forms for their records. The students were required to sign an additional assent form during the focus groups (Appendix C). These forms were collected by the researcher.

Quantitative Data Collection and Analysis

Quantitative Data Collection

Quantitative data were collected pre and post treatment using two instruments: the Middle School Science Inquiry Literacy Test, based on the Scientific Inquiry Literacy Test (Wenning, 2007b; Appendix D), and the Science Opinion Survey (Gibson, 2008; Appendix E).

The Science Opinion Survey was an appropriate science-attitude assessment tool for this study. Its length (30 items) is more student-friendly than the longer Test of Science Related Attitudes that has 70 items (Fraser, 1981) and the Science Attitude Inventory that has 40 items (Moore & Foy, 1997). It has the advantage of including both positive and negative items (as does the SAI II), and the wording of the questions is clearer, less complex, and more generally applicable to this study than the items on the SAI II. The Science Opinion Survey was originally developed by the National Association for Educational Progress and was adapted for the 1996 National Assessment of Educational Progress (N. L. Allen, Swinton, Isham, & Zelenak, 1998; Gibson & Chase, 2002; O’Sullivan & Weiss, 1999).
The Scientific Inquiry Literacy Test is a 35-question multiple-choice test intended to measure the ability of high school students to conduct scientific investigations based on the principles of scientific inquiry (Wenning, 2007a). The test was piloted with 425 high school students, and the KR20 reliability coefficient was 88%. Following the initial pilot, some of its questions were revised and replaced, and a second pilot with 61 different students was conducted. After the second pilot, a few of the questions were reworded for clarity, and the test was published. It is currently being used at Illinois State University as part of the Student Teacher Effectiveness Reporting System (Wenning, 2007a). The researcher contacted Dr. Wenning to obtain more information about the validation of the instrument as well as about the feasibility of using it for middle school students and/or what modifications might be made to make it more age appropriate (C. J. Wenning, November 15, 2012; November 17, 2012). Dr. Wenning granted permission to use the instrument (Appendix F). Based on Dr. Wenning’s feedback, a reworded 13-question version of the instrument was constructed, which is the Middle School Science Inquiry Literacy Test. According to Litwin (2003), the content validity of an instrument is the appropriateness of its items as determined by knowledgeable reviewers. A panel of six middle and high school science educators evaluated the Scientific Inquiry Literacy Test and the revised Middle School Science Inquiry Literacy Test to ensure the content validity and equivalence of the two assessments as well as the age appropriateness of the content and reading level (Litwin, 2003).

The Science Opinion Survey was designed to take about 15 minutes to complete, and the Middle School Science Inquiry Literacy Test was designed to take about 30 minutes for the students to complete, for a total of 45 minutes. The study’s preassessments were given in September through November, early in the science fair process and before the students
began the competition season for Science Olympiad. The post assessments for both groups
of students were given in either February or late March, after the regional competitions.

In order to preserve confidentiality, each student was given a unique confidential
identifier by his/her science teacher or Science Olympiad coach in order to match the pre
and post-assessments. The science teachers and Science Olympiad coaches did not share
the student names and identifiers with the researcher, and the researcher only received
coded assessments. In this dissertation and all publications, the schools and teachers were
given pseudonyms, and students were identified only in the aggregate.

Quantitative Data Analysis

The statistical analysis of the data collected through the Middle School Science Inquiry
Literacy Test and the Science Opinion Survey was based on four null hypotheses. There are
two null hypotheses relating to science inquiry skills: there is no difference in science inquiry
understanding as a result of participating in a science competition, and there is no difference
in science inquiry understanding between the science fair and Science Olympiad students.
There are also two null hypotheses relating to STEM attitudes: there is no difference in
student interest in STEM coursework or careers as a result of participating in a science
competition, and there is no difference in STEM interest between the students attending the
two types of competitions.

The data collected from the two administrations of the Middle School Science Inquiry
Literacy Test and the SOS were analyzed to determine whether there were differences in the
science fair versus Science Olympiad groups on the pretest, on the posttest, and to compare
growth for all of the groups from the pre to posttests. Statistical analyses were performed using PASW Statistics GradPack 18 published by SPSS, Inc. (2009). Descriptive statistics including minimum, maximum, mean, and standard deviation were collected for the Middle School Science Inquiry Literacy Test (inquiry test) and the Science Opinion Survey. For the inquiry test, the differences in the means on the pretest and posttest between groups were analyzed using the Independent Samples Mean Test. This test is used when there are two nonoverlapping groups to be compared (i.e. science fair and Science Olympiad students), and they are being compared on a quantitative value (i.e. their scores on the inquiry test; Field, 2009). The assumption for Independent Samples Mean Test is that the data are normally distributed. However, the values for the population in this study were not normally distributed, but according to Green and Salkind (2005), a sample size of at least 15 is adequate to yield reasonably accurate p values when normality is violated. The sample sizes of 24 and 25 in this study are sufficient to meet this criterion. A traditional t-test assumes the populations have equal variances, which was violated by the samples in this study; however, the Independent-Samples t-test does not make this assumption (Green & Salkind, 2005).

The Mann-Whitney U Test was used to evaluate the differences in means between the science fair and Science Olympiad groups for the SOS scores. This test is appropriate for samples in which there are two independent groups (i.e. science fair and Science Olympiad) and the quantitative values that are used for comparison are continuous (Green & Salkind, 2005). This test was used to evaluate the data because the SOS data were continuous, as opposed to the inquiry-test data that were based on the number of right or wrong answers to the test’s items.
To determine whether there were differences in the pre and post-test scores within the groups on both the inquiry test and the SOS, a Wilcoxon Signed Ranks Test was used. A Wilcoxon Signed Ranks Test is appropriate in studies in which a repeated-measures design is used, where the paired scores from an individual is independent of any other scores in the data set and where there are at least 16 sets of paired scores. A Wilcoxon is similar to the dependent t-test, but can be used when the data are not distributed normally (Field, 2009; Green & Salkind, 2005).

Limitations

In schools in which Science Olympiad was an extracurricular team activity, the students may have been self-selected and therefore may not have been representative of the school population. In addition, it was not possible to control for the effect of regular classroom instruction on any changes in attitudes or skills, because students were in different science classes.

Qualitative Data Collection and Analysis

Qualitative Data Collection

The purpose of the quantitative data collection for this study was to gather information about changes in student attitudes and understanding about science. However, science fairs and Science Olympiad were not the only science experiences the students engaged in during
the course of the study. Students received regular classroom science instruction. They may have also participated in informal science programs, such as extracurricular activities, classes, clubs, museum visits, enrichment programs, etc. Students may also have viewed science-themed television programs and movies and encountered science content on the Internet, in educational video games, and through visits to a library. The quantitative instruments used in this study were not designed to account for all of these effects. Therefore, students were invited to participate in focus groups and interviews in order to reveal more information about specific effects their participation in science competitions had on their attitudes and understanding about science.

Qualitative data collection through focus group interviews followed quantitative data collection in order to explore more deeply the themes that emerged from the quantitative data (Creswell, 2008). Therefore, the focus group interviews took place in February and March, after the pre and post quantitative data were collected. While Barbour (2008) cautions that focus groups are often misused and are a poor substitute for one-on-one interviews, she supports their use with children. Her reasoning is that they are less intimidating for children, and not all respondents need to answer all of the questions. However, the researcher needed to be sensitive to the comfort that a group setting provides for some students, while other students may be less likely to share their views in a group (Barbour, 2008). A group size of 6-8 students is recommended by Barbour (2008), which agrees with the researcher’s experience in facilitating focus groups of middle school students.

The classroom teachers were instructed to ask for volunteers for the focus groups. The researcher understood that this was a convenience sample, which is not an optimum
strategy but was practical in this context. Students who volunteered were required to have parental consent (Appendix C). From this pool of students, focus groups of 4-13 students were held during students’ regular class periods or during regularly scheduled Science Olympiad team meetings. These students were required to sign an assent form before participating (Appendix B). The focus groups lasted approximately 30 minutes and were audiotaped. The researcher took field notes.

Gaining useful information from a focus group is more likely if the questions and the procedure for conducting the session are carefully designed (Krueger, 1998; Krueger & Casey, 2000). An appropriate sequence of questions is important for obtaining useful information. Krueger (1998) suggests the following sequence of questions: opening, introductory, transition, key, and ending. In this sequence, the opening question helps the participants connect with each other and the topic to be discussed. Such a question should be easy to answer, should be answered by everyone, and should not highlight differences among participants but should bring the group together (Krueger & Casey, 2000). The introductory question should be answered by everyone as well, and should be an open-ended question that serves to focus attention on the topic to be discussed. Transition questions may ask participants to elaborate on their answers to the introductory questions, and move the group to the key questions. The key questions are those that relate directly to the research questions that the study is attempting to address. Finally, the ending questions bring closure to the session and give participants an opportunity to express any thoughts or opinions that did not come out in the discussion (Krueger, 1998; Krueger & Casey, 2000).
Focus Group Questions

These are the questions that were used in the focus groups for this study (they were worded appropriately depending on whether the group participated in a science fair or Science Olympiad):

1. What was the topic of your science fair project? What events did you participate in in Science Olympiad?
2. Thinking back, what was your favorite part of science fair/Science Olympiad?
3. List three things you learned about science from science fair/Science Olympiad?
4. Did you feel that you learned a lot about science by participating in science fair/Science Olympiad? In what way?
5. Do you think that you would like to become a scientist? What makes you think this?
6. Has participating in science fair/Science Olympiad changed your mind about becoming a scientist? In what way?
7. If you could tell me one thing about your experience in science fair/Science Olympiad, what would it be?

Focus Group Question Design

The design of the focus group questions was based on best practices suggested by Krueger and Casey (2000). The first question was an “opening question” (p. 44) that was answered by all of the participants for the purpose of making them feel comfortable, giving everyone an opportunity to talk, and setting the context for the session. The second question
was an “introductory question” (Krueger & Casey, 2000) that was answered by all of the participants. It was designed to help the participants think about their personal connection with the topic. The “thinking back” portion of the prompt was intended to have the participants reflect on how they felt about the experience at the time, rather than their current feelings (Krueger & Casey, 2000). The researcher wanted the sessions to remain positive and productive, so rather than inviting the students to complain about or criticize their teacher or the program, the students were asked only about their favorite part of the experience. The third question was a “transition question” (Krueger & Casey, 2000, p. 45) that moved the participants into the key questions of the study. Asking participants to make a list was found by Krueger and Casey (2000) to be a very effective technique for engaging focus group participants in the process of comparing and contrasting their lists and looking for common themes.

The fourth, fifth, and sixth questions were the key questions for the study, as they address science learning and attitudes and how they were affected by science competition participation. The students’ answers to the question about what they learned were analyzed for evidence of science inquiry understanding, and their answers to the follow-up question (i.e. whether they felt that they had learned about science in the competition) were analyzed for evidence of the effect of the competition on their learning. Questions 5 and 6, about their desire to pursue a career in science, were also analyzed for shifts in attitude toward STEM careers as a result of their participation in science competitions. Krueger and Casey (2000) point out that asking “why” or “why or why not” is a common mistake that focus group leaders make, that should be avoided because people sometimes find such wording threatening and subsequently become defensive. Their suggested wording is “in what way,”
which was incorporated into these questions. The fourth question was envisioned as a way to indirectly connect the quantitative data gleaned from the Middle School Science Inquiry Literacy Test and the students’ perceptions of how much they had learned. The fifth and sixth questions were meant to compliment the quantitative data collected through the Science Opinion Survey (Gibson, 2008). These connections were indirect because the students took the quantitative instruments anonymously, so the researcher did not know the focus group participants’ scores on these instruments. This was necessary to preserve confidentiality for the subjects and eliminate possible bias on the part of the researcher in conducting the focus group sessions. However, common themes emerged that informed the interpretation of the quantitative data. The key questions were discussed in an open format, with participants contributing at will. The last question was an “ending question” (Krueger & Casey, 2000, p. 45) whose purpose of the question was to bring closure to the session and to give the participants an opportunity to bring up any issues that they felt had not been covered. Once again, each participant was given a chance to contribute.

Protocol for Conducting the Focus Group Sessions

One type of protocol that can be used with a group is a structure with a set of guidelines and steps for a group discussion that allows for deep development of ideas (Easton, 2009). The protocol developed for the focus groups in this study was based on elements of Easton’s (2009) protocols for professional learning communities and Krueger and Casey’s (2000) suggestions for effective focus groups. Depending on the classroom configuration, students
were seated in a circle or in rows (either at desks or in chairs) or around a table. The procedure was as follows:

1. The researcher explained to the students the purpose of the focus group and gave an overview of the format and time frame. Any students who decided not to participate were allowed to leave. Students were informed that the sessions were being audiotaped and were asked to sign an assent form (Appendix C).

2. The students were given a list of the questions that would be asked. They were given 3-5 minutes to read, reflect, and free write about the questions (Easton, 2009). The purpose of having the students reflect and write was to give the students an opportunity to focus on the topic and think about their own views and opinions before hearing those of the other participants (Easton, 2009).

3. Question 1: all students answered, in any order they wished (Krueger & Casey, 2000).

4. Question 2: all students answered, but they were given the opportunity to pass if they wished (Easton, 2009).

5. Question 3: the group compiled a list on chart paper or on the chalkboard.

6. Questions 4, 5, and 6: open discussion, with students participating as they wished. The focus group leader ensured that anyone who wanted to speak could do so (Easton, 2009; Krueger & Casey, 2000).

7. Question 7: all students were asked to respond, but they were allowed to pass, if they wished (Easton, 2009).

8. The students were thanked for their time.
Qualitative Data Analysis

The researcher’s field notes were reviewed for possible themes relating to the research questions, and a preliminary set of codes was developed. The audio recordings of the focus groups were transcribed using a word processing program.

The researcher analyzed the transcripts using the protocol described by Maxwell (2005) wherein the comments in the transcripts were categorized and color-coded according to whether they related to STEM attitudes, science inquiry skills, or neither. Maxwell (2005) refers to these as “organizational” categories (p. 97), because they flow directly from the research questions and can reasonably be anticipated to come out in the focus group. In order to gain a deeper view of the participants’ experiences, the comments in each of the organizational categories were then coded to reflect the participants’ beliefs and attitudes, which Maxwell (2005) refers to as “substantive” categories (p. 97). Finally, the coded transcripts were examined for connections between the substantive codes and across organizational categories.

Limitations

There are two main limitations to the qualitative portion of this study. It must be remembered that while a group situation will be comfortable for some students, other students may not be comfortable sharing their insights in a group (Barbour, 2008). For some of the focus groups, the teacher was present, as required by school and/or district policy.
Seventh graders who participated in a science fair or Science Olympiad were the subjects of a sequential mixed-method study of their science inquiry skills and their attitudes toward STEM courses and careers. Quantitative data collection was followed by qualitative data collection through focus groups. Quantitative analysis included descriptive statistics, the Independent Samples Mean Test, the Wilcoxon Signed Ranks Test, and the Mann-Whitney U Test. Qualitative data was analyzed through coding of organizational and substantive categories and overall themes. The next chapter examines the data.
CHAPTER 4

RESULTS

Introduction

The focus of this chapter is the presentation and analysis of the data collected in the study. Interpretations and implications of the results are in Chapter 5. Both quantitative and qualitative data were collected from seventh-grade students at six schools. Students at two additional schools provided only qualitative data through focus groups. Quantitative data were collected through administration of the Science Opinion Survey and the Middle School Science Inquiry Literacy Test. The data are reported relative to the research questions:

RQ1. Does formal science competition participation in middle school promote an increase in the understanding of science inquiry?

RQ2. Does formal science competition participation increase middle school student interest in studying STEM subjects and pursuing STEM careers?

RQ3. Are there differences in the understanding of science inquiry among middle school students who participated in science fairs and those who participated in Science Olympiad?

RQ4. Are there differences in attitudes toward STEM subjects and careers among middle school students who participated in science fairs and those who participated in Science Olympiad?
Characteristics of Participating Schools

Science Fair Schools

Seventh-grade students at three parochial schools, for which demographic data are not available, provided both quantitative and qualitative data related to science fairs. School “A” (SFA) was a suburban school in the Diocese of Chicago, IL. School “B” (SFB) was a suburban school in the Diocese of Joliet, IL. School “C” (SFC) was located in a small city in the Diocese of Rockford, IL. SFC provided aggregate fifth-grade percentile scores on the Iowa Test of Basic Skills for the seventh grade students who participated in the study: reading 94%; language 98%; math 75%; and composite 87%.

Science Olympiad Schools

Five Science Olympiad schools participated in the study. For the purposes of the study, they are designated SOA, SOB, SOC, SOD, and SOE. Three of the schools provided both quantitative and qualitative data (SOA, SOB, SOC), and two schools provided only qualitative data (SOD and SOE). Because Science Olympiad is a voluntary extracurricular activity, the demographics of a school as a whole do not necessarily reflect the demographics of the Science Olympiad participants at that school. Schools SOA, SOD, and SOE were located in the Chicago, IL, suburbs, SOC was a rural school in Illinois, and SOB was located in an Illinois suburb of St. Louis, MO. The demographics in Table 5 were obtained from the Illinois State Board of Education website and reflect data collected during the 2012-2013
school year (Illinois State Board of Education, 2014). The Illinois Standard Achievement Test (ISAT) is given in grades 3 through 8 for mathematics and reading, and grades 4 and 7 for science. Therefore, the overall score does not include science (Illinois State Board of Education, n.d.). The student performance levels are cut points determined through statistical analysis of standards and based on the age of the students. These cut points are exceeds standards, meets standards, below standards, and academic warning (Illinois State Board of Education, n.d.; Northern Illinois University, 2014). The data shown in Table 5 are whole school scores.

Quantitative Data

Quantitative data were collected through the Middle School Science Inquiry Literacy Test and the Science Opinion Survey. The Middle School Science Inquiry Literacy Test is a revision created by the researcher of the Scientific Inquiry Literacy Test designed for high school students (Wenning, 2007a, 2007b). Both instruments were administered using the protocol approved by the Northern Illinois University Office of Research Compliance and Integrity early in the science fair process and at the beginning of the Science Olympiad season (before the students had attended any competitions). They were again administered after the regional competitions for both groups. The students’ confidentiality was protected by having the students put a code assigned by their teachers or Science Olympiad coaches, rather than their names, on each instrument so that the pre and postassessments for each student could be matched. Only complete sets of student data were included in the study. A complete set of
Table 5  
*Science Olympiad School Demographic Data, 2012-2013 (Percent)*

<table>
<thead>
<tr>
<th>School</th>
<th>ISAT Math</th>
<th>ISAT Reading</th>
<th>ISAT Overall</th>
<th>ISAT Science</th>
<th>African American</th>
<th>Asian</th>
<th>Hispanic/Latino</th>
<th>White</th>
<th>Low Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOA</td>
<td>81</td>
<td>86</td>
<td>83</td>
<td>94</td>
<td>3</td>
<td>20</td>
<td>12</td>
<td>60</td>
<td>9</td>
</tr>
<tr>
<td>SOB</td>
<td>64</td>
<td>57</td>
<td>61</td>
<td>91</td>
<td>49</td>
<td>2</td>
<td>6</td>
<td>33</td>
<td>42</td>
</tr>
<tr>
<td>SOC</td>
<td>55</td>
<td>57</td>
<td>56</td>
<td>83</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>96</td>
<td>47</td>
</tr>
<tr>
<td>SOD</td>
<td>84</td>
<td>82</td>
<td>83</td>
<td>92</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>84</td>
<td>6</td>
</tr>
<tr>
<td>SOE</td>
<td>92</td>
<td>96</td>
<td>96</td>
<td>100</td>
<td>2</td>
<td>26</td>
<td>3</td>
<td>63</td>
<td>8</td>
</tr>
</tbody>
</table>

data for a student was defined as including both a pretest and a posttest for the Middle School Science Inquiry Literacy Test and a presurvey and postsurvey for the Science Opinion Survey.

The Middle School Science Inquiry Literacy Test is a 13-question multiple-choice test. The Middle School Science Inquiry Literacy Tests were scored manually, and the total scores were entered into a database. The Science Opinion Survey is a 30-question survey using a Likert scale, with 1 being “strongly agree” and 5 being “strongly disagree.” Many of the statements on this survey are worded so that the students need to think carefully about their answers, rather than just choose “strongly agree” or “strongly disagree” for every statement. According to Patten (2001), writing survey items so that some are positive and others are negative regarding the topic is important for avoiding bias related to response sets in which respondents tend to agree or disagree with every item. For example, one statement is “science lessons are fun,” while another is “I dislike science lessons.” Therefore, the positive statements were reverse-coded after they were entered into the database so that the students’ scores would accurately reflect their attitude toward science, with higher scores indicating a more positive attitude. The students’ responses to each statement on the Science Opinion Surveys were entered into the same database, and each student’s score was calculated electronically.
Research Questions 1 and 3: Middle School Science Inquiry Literacy Test

The Middle School Science Inquiry Literacy Test was used to collect data pertaining to RQ1 and RQ3. These questions pertained to student understanding of science inquiry as a result of participating in a science competition, and differences in this understanding between science fair and Science Olympiad groups. A summary of the data is in Table 6. There were 13 items on each test. The “maximum student score” is the highest score achieved by any student on the test.

Table 6
Middle School Science Inquiry Literacy Test

<table>
<thead>
<tr>
<th>Group and test</th>
<th>N</th>
<th>Minimum student score</th>
<th>Maximum student score</th>
<th>Mean score</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test, all students</td>
<td>49</td>
<td>3</td>
<td>13</td>
<td>8.02</td>
<td>2.780</td>
</tr>
<tr>
<td>Post-test, all students</td>
<td>49</td>
<td>3</td>
<td>12</td>
<td>8.51</td>
<td>2.467</td>
</tr>
<tr>
<td>Pre-test, science fair</td>
<td>25</td>
<td>3</td>
<td>13</td>
<td>6.56*</td>
<td>2.583</td>
</tr>
<tr>
<td>Post-test, science fair</td>
<td>25</td>
<td>3</td>
<td>12</td>
<td>7.76</td>
<td>2.350</td>
</tr>
<tr>
<td>Pre-test, Science Olympiad</td>
<td>24</td>
<td>5</td>
<td>13</td>
<td>9.54</td>
<td>2.105</td>
</tr>
<tr>
<td>Post-test, Science Olympiad</td>
<td>24</td>
<td>3</td>
<td>12</td>
<td>9.29</td>
<td>2.386</td>
</tr>
</tbody>
</table>

Note. There were 13 items on each test. *p = 0.001.

Nonparametric statistical methods were employed to analyze the data, because the values for some of the groups were not normally distributed. Based on the Wilcoxon Signed Ranks Test, there was no significant difference in the pretest and posttest scores for either group (science fair p = 0.084 and Science Olympiad p = 0.502). Therefore, for Research
Question 1, the null hypothesis that there was no difference in science inquiry understanding as a result of participating in a science competition was confirmed.

Research Question 3 addressed differences between the science fair and Science Olympiad groups. In this case, the null hypothesis that there was no difference between groups was rejected. Based on the Independent Samples Mean Test, there was a significant difference in pretest scores between the science fair and Science Olympiad groups ($p = 0.001$), with the scores for the science fair group being significantly lower. However, based on the Independent Samples Mean Test, the posttest scores were not significantly different ($p = 0.056$).

An analysis of student performance on the individual items of the Middle School Science Inquiry Literacy Test supports the contention that the science fair students made gains in science inquiry understanding (Table 7). The number of Science Olympiad students who answered items correctly remained essentially the same from the pretest to the posttest, with an overall decrease of 0.6 questions answered correctly as a group and a decrease in the mean score of 0.25. In contrast, from the pretest to the post-test, science fair students answered 1.9 more questions correctly as a group and had an increase of 1.2 in the mean score. While these values are not statistically significant, they suggest that the science fair students experienced a gain in science inquiry understanding: their scores improved on seven test items, while the Science Olympiad students improved on only two items.

It is worth noting that science fair students and Science Olympiad participants were drawn from different pools of students. The science fair students were conducting their projects as a class assignment, whereas the Science Olympiad students were participating in a voluntary extracurricular activity. This difference in the participating populations could
Table 7
Middle School Science Inquiry Literacy Test: Correct Responses by Item

<table>
<thead>
<tr>
<th>Item</th>
<th>Science fair pre-test</th>
<th>Science fair post-test</th>
<th>Change pre-to post-test</th>
<th>Science Olympiad pre-test</th>
<th>Science Olympiad post-test</th>
<th>Change pre-to post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>16</td>
<td>+4</td>
<td>18</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>19</td>
<td>19</td>
<td>0</td>
<td>22</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>12</td>
<td>-1</td>
<td>13</td>
<td>10</td>
<td>-3</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>6</td>
<td>-1</td>
<td>13</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>22</td>
<td>19</td>
<td>-3</td>
<td>21</td>
<td>20</td>
<td>-1</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>6</td>
<td>-2</td>
<td>15</td>
<td>9</td>
<td>-6</td>
</tr>
<tr>
<td>7</td>
<td>19</td>
<td>19</td>
<td>0</td>
<td>23</td>
<td>24</td>
<td>+1</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td>15</td>
<td>+5</td>
<td>20</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>15</td>
<td>20</td>
<td>+5</td>
<td>21</td>
<td>19</td>
<td>-2</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>9</td>
<td>+4</td>
<td>11</td>
<td>12</td>
<td>+1</td>
</tr>
<tr>
<td>11</td>
<td>17</td>
<td>22</td>
<td>+5</td>
<td>22</td>
<td>23</td>
<td>+1</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>14</td>
<td>+6</td>
<td>15</td>
<td>16</td>
<td>+1</td>
</tr>
<tr>
<td>13</td>
<td>13</td>
<td>16</td>
<td>+3</td>
<td>16</td>
<td>16</td>
<td>0</td>
</tr>
</tbody>
</table>


explain the differences in scores. The Science Olympiad students started at a higher level on the pretest but did not experience a gain in scores, while the science fair students started lower but experienced a gain in scores, although their increase was not statistically significant.
The Science Opinion Survey was administered in order to gather data about Research Questions 2 and 4. Research Question 2 concerns changes in student attitudes as a result of participating in science competitions, while Research Question 4 focuses on the difference in attitudes between students who participated in science fairs and Science Olympiad. The Science Opinion Survey asked students to rate statements about their attitudes on a 5-point Likert scale, with 1 being “strongly agree” and 5 being “strongly disagree.” Both positive and negative statements were given, and the scores were reverse-coded as appropriate. Higher scores indicate a more positive attitude, with a 5 being the maximum positive score. Table 8 summarizes the data.

Table 8

<table>
<thead>
<tr>
<th>Group and survey</th>
<th>N</th>
<th>Minimum score</th>
<th>Maximum score</th>
<th>Mean score</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-survey, all students</td>
<td>49</td>
<td>1.77</td>
<td>4.77</td>
<td>3.55</td>
<td>0.730</td>
</tr>
<tr>
<td>Post-survey, all students</td>
<td>49</td>
<td>1.03</td>
<td>4.90</td>
<td>3.63</td>
<td>0.773</td>
</tr>
<tr>
<td>Pre-survey, science fair</td>
<td>25</td>
<td>1.77</td>
<td>4.77</td>
<td>3.23*</td>
<td>0.719</td>
</tr>
<tr>
<td>Post-survey, science fair</td>
<td>25</td>
<td>1.03</td>
<td>4.73</td>
<td>3.31**</td>
<td>0.836</td>
</tr>
<tr>
<td>Pre-survey, Science Olympiad</td>
<td>24</td>
<td>2.93</td>
<td>4.77</td>
<td>3.89*</td>
<td>0.585</td>
</tr>
<tr>
<td>Post-survey, Science Olympiad</td>
<td>24</td>
<td>3.10</td>
<td>4.90</td>
<td>3.96**</td>
<td>0.541</td>
</tr>
</tbody>
</table>

Note. *p = .001, **p = .004.

Nonparametric techniques were used to analyze the data, because the values for some of the groups were not normally distributed. Based on the Wilcoxon Signed Ranks Test,
which is appropriate for data sets in which there are pairs of repeated measures that are independent of the other pairs in the set (Green & Salkind, 2005), there was no significant difference in the pretest and posttest scores for either group (science fair \( p = 0.08 \), and Science Olympiad \( p = 0.502 \)). Therefore, the null hypothesis for Research Question 2 that participation in a science competition does not increase middle school student interest in STEM coursework or careers, was confirmed.

Research Question 4 concerns differences in student STEM-related attitudes between the science fair and Science Olympiad groups. There was a significant difference in the presurvey and postsurvey scores between the groups. Based on the Mann-Whitney U Test, which is useful when there are two independent groups and the data are continuous (Green & Salkind, 2005), the significance for the presurvey was \( p = 0.001 \), and the post-survey was \( p = 0.004 \), with the science fair group having lower scores on both measures. This result was be expected because Science Olympiad students volunteer to participate in an extracurricular activity, while science fair students are engaged in a required class assignment. The null hypothesis was rejected, as there was a significant difference in attitudes about science between the science fair and Science Olympiad groups, with the Science Olympiad group being more favorable in their attitudes toward STEM courses and careers.

Data Disaggregated by School

Further analysis of the data was conducted by disaggregating the data for both instruments by school. The data were not normally distributed, and the sample sizes were less than 15; therefore, reliable \( p \) values could not be generated (Field, 2009; Green &
Salkind, 2005). However, it is possible to observe some general trends in the data. The results are summarized in Table 9.

Table 9
Data Disaggregated by School: Mean Scores

<table>
<thead>
<tr>
<th>School</th>
<th>N</th>
<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>49</td>
<td>3.55</td>
<td>3.63</td>
<td>8.02</td>
<td>8.51</td>
</tr>
<tr>
<td>SFA</td>
<td>12</td>
<td>2.77</td>
<td>2.81</td>
<td>7.08</td>
<td>8.17</td>
</tr>
<tr>
<td>SFB</td>
<td>2</td>
<td>3.25</td>
<td>3.83</td>
<td>5.00</td>
<td>6.00</td>
</tr>
<tr>
<td>SFC</td>
<td>11</td>
<td>3.73</td>
<td>3.76</td>
<td>6.27</td>
<td>7.64</td>
</tr>
<tr>
<td>SOA</td>
<td>11</td>
<td>3.77</td>
<td>3.91</td>
<td>10.27</td>
<td>10.45</td>
</tr>
<tr>
<td>SOB</td>
<td>4</td>
<td>4.44</td>
<td>4.13</td>
<td>6.50</td>
<td>7.25</td>
</tr>
<tr>
<td>SOC</td>
<td>9</td>
<td>3.79</td>
<td>3.94</td>
<td>8.78</td>
<td>10.00</td>
</tr>
</tbody>
</table>

The two schools that had means on the Science Opinion Survey that varied the most from the overall pretest and posttest means were SFA (lower than the overall pretest and posttest means), and SOB (higher than the overall pretest mean of 3.55 and posttest mean of 3.63). All of the science fair schools had inquiry-test scores that were lower than the mean, but SFB had a post Science Opinion Survey score higher than the mean, and for SFC, both the pre- and post-SOS scores were higher than the mean. For the Science Olympiad schools, both SOA and SOC had scores higher than the mean on the inquiry test and the SOS. However, while SOB had the highest score on the SOS, its inquiry score was below the mean. There is an apparent disparity between attitude and inquiry scores for both science fair and Science Olympiad schools because a positive attitude did not necessarily translate into a
correspondingly high inquiry score. An explanation of this phenomenon may lie in the different pools of students who participated in these competitions. For example, the students at SFA were required to participate in their school science fair, so they may have had lower attitude scores to begin with, unrelated to their inquiry scores. Conversely, the students at SOB were voluntarily participating in an extracurricular activity and thus had a more positive attitude toward science, if not the highest inquiry scores. It should be noted that, while not statistically significant, all of the Science Olympiad schools and only one of the science fair schools had presurvey and postsurvey attitude scores above the mean. Two of the Science Olympiad schools and none of the science fair schools had inquiry scores above the mean. This is further evidence that the pool of students who participated in these competitions were not necessarily equivalent in attitude toward science and in their understanding of science inquiry.

**Summary of the Quantitative Data**

Research Questions 1 and 2 addressed the effect of science competition participation on student understanding of science inquiry and attitudes toward STEM courses and careers, respectively. Based on the quantitative data, the null hypothesis was supported for both questions. Participation in science competitions did not significantly affect science inquiry skills or science attitudes. The data support Research Questions 3 and 4 in that there were differences between the two groups in their inquiry skills and attitudes. However, these differences seem to be a result of the pool from which the students were drawn, rather than an effect of participating in the competitions. It stands to reason that a student who voluntarily
spends time outside of school participating in science activities has a more positive attitude toward science and perhaps (but not necessarily) a higher inquiry score.

Limitations of the Quantitative Data

The quantitative data analysis was limited by the relatively small sample sizes, especially when disaggregated by school. The use of parametric statistical analysis was not possible due to the nonnormal distribution of the values for several of the groups and the violation of homogeneity of variance by some of the groups. Therefore, the data that were disaggregated by school should be interpreted with caution. Science competitions are not the only science instruction or experiences that the students engaged in during the study period, so any effects seen may not be entirely attributed to science competition participation. In addition, a control group (i.e. schools that did not participate in science competitions) would have shed light on the data. However, no such schools agreed to participate in the study.

Qualitative Data

Qualitative data were collected through focus groups of 4-13 students conducted at eight schools. At some of the schools, there was more than one focus group, depending on the number of students who wished to participate. A total of 86 students participated in focus groups; 41 science fair students and 45 Science Olympiad students. The sessions were conducted during class time or during regularly scheduled afterschool Science Olympiad meetings. At four of the schools, the teacher was present in the room, as required by school
policy. Five focus groups of science fair students were conducted at three schools. Seven focus groups of Science Olympiad students were held at five schools.

Audio recordings of the focus groups were transcribed, and the student responses were categorized according to themes related to the research questions and further categorized into subthemes. Table 10 provides a summary of the themes and subthemes. Many students made comments that did not relate directly to the research questions but that revealed their attitudes toward the competitions. These responses are addressed in a separate section. It is important to note that students were not required to answer the questions, so the numbers in Tables 11, 12, and 13 are based on the number of students responding to that question, not the total number of students in the focus groups.

Research Questions 1 and 2: Understanding of Science Inquiry

RQ1. Does formal science competition participation in middle school promote an increase in the understanding of science inquiry?

RQ2. Does formal science competition participation increase middle school student interest in studying STEM subjects and pursuing STEM careers?

A summary of the students’ responses regarding science inquiry is in Table 11. Subthemes relating to the theme of science inquiry were an increase in general science knowledge, evidence of procedural knowledge, designing and conducting an experiment, evaluating the correctness of a hypothesis, and using a procedure to improve performance.
Table 10  
*Qualitative Data Analysis: Themes and Subthemes*

<table>
<thead>
<tr>
<th>Theme</th>
<th>Subtheme</th>
<th>Indicator</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science inquiry</td>
<td>Increase in general science knowledge</td>
<td>Students indicated that he/she had learned science content</td>
<td>“I learned about the four forces on an airplane.”</td>
</tr>
<tr>
<td></td>
<td>Evidence of procedural knowledge</td>
<td>Speaking in general about how to conduct an experiment</td>
<td>“I learned how to use variables.”</td>
</tr>
<tr>
<td></td>
<td>Design experiment, collect and analyze data</td>
<td>Evidence that the student had conducted an experiment, collected data, and analyzed the data</td>
<td>“I learned that natural sponges are more absorbent than synthetic sponges.”</td>
</tr>
<tr>
<td></td>
<td>Evaluate correctness of hypothesis</td>
<td>Student used the term “hypothesis” correctly</td>
<td>“My hypothesis was perfectly correct…”</td>
</tr>
<tr>
<td></td>
<td>Used a process to improve performance</td>
<td>Students can describe a process for improving a device</td>
<td>“In helicopters we used to go out and test them…”</td>
</tr>
<tr>
<td>Attitudes toward STEM</td>
<td>Desire to pursue a career in science</td>
<td>Student indicated an interest/no interest in a science or science-related career</td>
<td>“It seems too difficult to be a scientist or science teacher.”</td>
</tr>
<tr>
<td>courses and careers</td>
<td>Influence of science competition on the desire to pursue a career in science</td>
<td>Student indicated that science competition influenced his/her desire to pursue a career in science</td>
<td>“I’d say that after doing the science, fair it more inclined me to become a scientist…”</td>
</tr>
<tr>
<td></td>
<td>Influence of science competition on attitude toward science courses</td>
<td>Student indicated an enjoyment of studying science</td>
<td>“I liked Science Olympiad because it…brought me into the depths of science.”</td>
</tr>
</tbody>
</table>

(continued on following page)
Table 10 (continued)

<table>
<thead>
<tr>
<th>Theme</th>
<th>Subtheme</th>
<th>Indicator</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other Themes</td>
<td>Favorite part of the science fair process</td>
<td>Student mentioned components of the science fair process, including background research, experimentation, making the presentation board, and presenting</td>
<td>“I liked to organize the board how I wanted it…”</td>
</tr>
<tr>
<td></td>
<td>Teamwork and Competition</td>
<td>Science Olympiad student commented about teamwork and competition</td>
<td>“I had never really been on any other teams other than Science Olympiad, but I liked the teamwork the best.”</td>
</tr>
<tr>
<td></td>
<td>Hard Work</td>
<td>Student commented about the effort involved in science fair and Science Olympiad</td>
<td>“Science takes a lot of effort, but it was worth it.”</td>
</tr>
</tbody>
</table>

Table 11

*Theme: Science Inquiry*

<table>
<thead>
<tr>
<th>Subthemes</th>
<th>Science fair</th>
<th>Science Olympiad</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$N = 41$</td>
<td>$N = 45$</td>
</tr>
<tr>
<td>Increase in general science subject knowledge</td>
<td>$n = 15$</td>
<td>$n = 26$</td>
</tr>
<tr>
<td>Evidence of procedural knowledge</td>
<td>$n = 8$</td>
<td>$n = 0$</td>
</tr>
<tr>
<td>Design experiment, collect and analyze data</td>
<td>$n = 27$</td>
<td>$n = 0$</td>
</tr>
<tr>
<td>Evaluate correctness of hypothesis</td>
<td>$n = 7$</td>
<td>$n = 0$</td>
</tr>
<tr>
<td>Used a process to improve performance</td>
<td>$n = 0$</td>
<td>$n = 18$</td>
</tr>
</tbody>
</table>
The subtheme of “increase in general science knowledge” was defined as responses in which the students indicated that they had learned science content. Examples of this type of response are “I learned about the four forces on an airplane” and “I got to learn about how energy builds up, and how it flows, and how it stops, and how it can light the simplest bulbs.” Both science fair and Science Olympiad students indicated that they had learned science content as a result of their participation, but it was mentioned more often by the Science Olympiad students.

The subtheme of “evidence of procedural knowledge” was defined as speaking in general about how to conduct an experiment. These responses showed an awareness of how to design and conduct an experiment without including specific details. Examples of these responses are “I learned how to use variables,” “I learned more about the planning part and the process of it,” and “because we had to go through the procedure and the hypothesis and figure out how to do the actual experiment.” Science fair students made this type of comment, Science Olympiad students did not.

The subtheme of “design experiment, collect and analyze data,” was most pertinent to the experiences of the science fair students. Responses that implied that the student engaged in this activity were included such as “I learned that natural sponges are more absorbent than synthetic sponges” because in order for each such a conclusion, the student would have had to conduct an experiment, collect data, and analyze that data. Some students described their process in detail. This subtheme’s responses came mostly from the students’ comments when asked to describe their project. The Science Olympiad students were instead asked about their event participation. It is possible that Science Olympiad students also had experience
designing experiments and collecting and analyzing data, but that was not expressed in the focus groups.

In order for a response to be categorized in the subtheme “evaluate the correctness of a hypothesis,” the student had to use the term “hypothesis” correctly in their comments. Examples of comments categorized in this sub-theme are, “I learned that sometimes you can be really wrong about your hypothesis. I mean, yes, my hypothesis was true, but the product that I thought would be the least good actually came out to be second best” and “My hypothesis was perfectly correct. I tested people by themselves, or in groups of two, or in big groups.” Once again, these comments were made when the science fair students were asked to describe their project.

Science Olympiad competitions include several “building” events, in which the students build and perfect items such as a helicopter or a wheeled vehicle. As a follow-up question to the question about their event participation, the researcher asked students to describe their process for improving their building-event items. Examples of responses in this subtheme are, “In helicopters, we used to go out and test them. Sometimes it would hit the ceiling and break. We would try to figure out what it was, and try to make it better” and

For rotor egg drop, we would test it, and sometimes it wouldn’t turn. You have to try to move the wings around and try different things. At Invitational, it broke, and we had to try to rebuild and fix it.

Another student commented,

With our helicopter, we had a kit, and then we knew exactly what to do. After we built the helicopter exactly the way it was in the kit, we realized it was way too heavy, and so we made modifications, and that is what we’re doing right now.
One student said

So you just start out with what you and your partner think is best, but sometimes it really isn’t the best thing. You just have to figure out where you went wrong, and you just have to keep making it better.

Nearly all of the students commented about the trial-and-error aspects of the process, and one student said that “They’re really not experimentation events, they’re more of the engineering aspect.” While the Science Olympiad students who participated in building events may not have formally engaged in science inquiry as defined by the scientific method (as practiced in science fairs), they were using inquiry and experimentation skills to improve the performance of the objects they were building.

In summary, many of the students from both competitions increased their general science knowledge through their participation (science fair n = 15, Science Olympiad n = 26). The science fair students in particular expressed an understanding of science inquiry as hypothesis-testing through designing and conducting an experiment (design and conduct an experiment n = 27, evaluate the correctness of a hypothesis n = 7). The Science Olympiad students exhibited a more informal understanding of inquiry through testing and perfecting their items in the building portions of the competition (n = 18). Therefore, the qualitative evidence supports the contention that participation in formal science competitions increases middle school students’ understanding of science inquiry (Research Question 1). The evidence is murkier regarding the differences in understanding between the two groups (Research Question 3). While the understanding of formal science inquiry (through the steps of the scientific method) is fairly clear for the science fair students, an understanding of science inquiry for Science Olympiad students appears to be more informal. Therefore, while it
appears that the evidence supports Research Question 3, in that there were differences in the understanding of science inquiry between the two groups, more research needs to be done to better understand these differences.

Research Questions 2 and 4: Attitudes Toward STEM Subjects and Careers

Data from student responses to questions about their attitudes toward STEM courses and careers are summarized in Table 12. Subthemes were the students’ desire to become a scientist, whether participation in a science competition influenced that desire, and the effect of participating in science competitions on their attitudes towards STEM courses.

Table 12
Theme: Attitudes Toward STEM Subjects and Careers

<table>
<thead>
<tr>
<th>Subtheme</th>
<th>Science fair</th>
<th>Science Olympiad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desire to pursue a career in science</td>
<td>$n = 23$</td>
<td>$n = 29$</td>
</tr>
<tr>
<td></td>
<td>Yes = 7</td>
<td>Yes = 18</td>
</tr>
<tr>
<td></td>
<td>Science-related field (as defined by student) = 1</td>
<td>Science-related field (as defined by student) = 2</td>
</tr>
<tr>
<td></td>
<td>No = 11</td>
<td>No = 3</td>
</tr>
<tr>
<td></td>
<td>Don’t know/ need more information = 4</td>
<td>Don’t know/ need more information = 6</td>
</tr>
<tr>
<td>Influence of science competition on the desire to pursue a career in science</td>
<td>$n = 14$</td>
<td>$n = 27$</td>
</tr>
<tr>
<td></td>
<td>Positive = 9</td>
<td>Positive = 19</td>
</tr>
<tr>
<td></td>
<td>Negative = 5</td>
<td>No change = 7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Negative = 1</td>
</tr>
<tr>
<td>Influence of science competition on attitude toward science courses</td>
<td>$n = 58*$</td>
<td>Made science fun = 9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Broadened the scope of science = 7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More in depth than usual classes = 31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Learned a lot = 11</td>
</tr>
</tbody>
</table>

Note. *Some students gave more than one response.
Science Fair Student Attitudes

Eight of 23 (34.8%) science fair students who responded to the question about the desire to pursue science as a career indicated an interest in a science or science-related career.

One student commented,

Maybe because I think it’s interesting to learn about new things, how you can do it yourself, and then you come up with this hypothesis, and you come up with a conclusion, and you did it all yourself. And it’s something new you didn’t know.

Another commented,

I would say yes because even though the field of medical stuff really interests me, I also think that experimenting and doing lots of searching, I think that sounds fun, like archeology. That science really sounds fun too.

One student stated,

So I would like to become a scientist, so I like engineering, and a key part of engineering is science. So that would kind of make me a scientist, so the reason that I would like to become that is because I just enjoy it.

Several students stated that they were not interested in a science career because of their perception of the stress level and difficulty it would entail. Such comments included, “Science is very stressful,” “I don’t think that I would like to be a scientist because I stressed out over my experiment, more stressed out than any project that I had ever done,” and “It seems too difficult to be a scientist or a science teacher.” One student commented,

I’m going to have to say no because I feel like I would struggle a lot, because I’m also not very patient and stuff. And because I don’t think I would be able to understand what I would be doing.
When asked the follow-up question about whether participating in the science fair changed their opinion about wanting to be a scientist, 9 of 14 students responding indicated that it had changed their attitude in a positive way. However, only a small number of the students answered this question. Positive comments included, “I’d say that after doing the science fair, it more inclined me to become a scientist because it answered some of my questions” and “Before, in previous grades, I was not as interested in science because we didn’t learn anything exciting. But now that I’ve done actual experiments and stuff, I think it is more exciting.”

Another student commented:

I don’t think I would become a scientist, but doing science fair has kind of grabbed by attention a little more on that. I don’t think that I would devote my life to science, but it kind of grabbed my attention a little.

As with the previous question, the negative comments made by the students focused on their perception of the difficulty and stress level of pursuing science. Student comments included, “I learned a lot of interesting facts, and I want to keep learning, but it seems too hard,” “Well, before, I thought that being a scientist was not as hard, but you have to take a lot of time, and it is hard, actually,” and “Not really, I found out that my data and everything [was] pretty disorganized, and I had to like at the last minute, organize it all. I couldn’t really become a scientist.” Based on the students’ comments, participating in a science fair was a positive experience for some students and negative for others. For some students it was both, as one student commented,

Pretty much yes and no, but mostly no, because I’m pretty disorganized, I would probably struggle with being organized. But yes, because, you know, I want to be a doctor someday. I think that science could help me along that path.
The wide range of student attitudes may have contributed to the rather noncommittal quantitative data, if the positive and negative students were cancelling each other out in the mean scores. However, it is of concern that based on some of the student comments, the competition experience may have discouraged some students who may have had positive attitudes toward science and scientists prior to their participation.

Science Olympiad Student Attitudes

Twenty of 29 Science Olympiad students who responded to the question about their desire to pursue a career in science or a science-related field expressed a positive interest. Their comments included, “I’d say yes, too, because science it seems like it has never-ending questions that need to be solved; you’ll get a question, then another question, like a series of questions,” “Yes, I want to be a scientist because I want to apply what I know to what I do,” and “Yes, because science can really help to move the world to a better place, whereas like other subjects might not have the same impact.” The students who indicated they were not interested in a science career gave reasons such as not having enough information to make a decision or interest in other career areas.

When asked about the influence of Science Olympiad on their career aspirations, 19 of 27 students who responded to the question stated that their participation had a positive effect on their views. Fourteen of these students indicated that participation in Science Olympiad had increased their awareness of what scientists really do. An example of their comments is, “Yes, because I used to think being a scientist was just dealing with chemicals and stuff, there’s more than just that.” One student commented that
Before, I had a very narrow view of science, but when you go to Science Olympiad, you are learning everything in a different way; it is like widening your view. So I think definitely it encouraged me to want to be a scientist.

Another stated,

At the beginning of the year, like I didn’t want to be a scientist at all; I just thought it was like you would just go in the lab and do stuff. But at the end, you realize that you can do different stuff and be a scientist. It’s not just the stuff you do at school.

One student commented,

I’d say it gave me a new respect for scientists. In my first year I had this really shallow idea of science. They said, “Take a glaciers test,” and I said, “How bad could glaciers possibly be?” So I didn’t study, and when I actually did the test it was really sad. I did finish really fast, because I didn’t know many of the answers. It gave me a new respect for scientists.

Another student contrasted his/her Science Olympiad experience and his/her science instruction in school:

I’d say yes that Science Olympiad shows you things that you don’t learn in school. It changes your view on science from what you do in school. School is like a lot of test and book work; here there’s a lot of building, and designing, and experimentation. It gives you a better view of what a scientist career would be like.

Of the students who indicated that Science Olympiad did not change their opinions about pursuing a science career, four stated that they joined the team because they had already decided to become scientists. For example, one student stated,

Not really, because I have always had this thought about being a scientist. When I was little, science was always my favorite subject, and now that I’m older it still is. It enforces it, but I’ve always thought about that.

Another student commented,
I don’t think it changes, because I always wanted to be a scientist. Like in 1st grade we studied the planets, so I decided I wanted to be an astronomer. I think Science Olympiad just strengthened that wanting and the love of science.

While the students were not asked directly about the influence of their Science Olympiad participation on their interest in STEM coursework, this was a common theme in the focus groups. A majority of the students (31) commented about their enjoyment of studying science topics in greater depth than they were able to in their regular science classes and that they enjoyed the challenge of working on more challenging material. Student comments included, “I was interested in the human body, but I didn’t think that it would be as complex as I think now” and “I liked Science Olympiad because it was the first thing that involved science that brought me into the depths of science. It’s the first program to ever do that.” One student commented,

One of my favorite things about Science Olympiad is that we get to be challenged, and we get to improve our weaknesses. It’s not like we get regular material that every middle schooler would have; we get challenged by material that is above our usual.

Another stated that,

I didn’t know the parts of science were that closely related. Like you wouldn’t think that you would find things about electricity and magnetism in anatomy, right? But there is action potential where you talk about the voltage of the signals, and you realize that they are really closely related.

One student commented,

Like for Heredity and Water Quality, you wouldn’t think that those things are really closely related, or have anything in common. But in Water Quality we study invasive species, like animals, and how they reproduce and everything, which has something to do with heredity.
Another stated that,

> Like for Solar System, I’ve studied the solar system for a while, but I haven’t gone in depth. As you study it you realize how closely related it is to our evolution, and how we became us. I also think it is helpful for all the study events it helps you take notes better.

Application of learning was important to one student, who stated that,

> I think I learned a lot in areas that I thought I knew a lot about, like, say, simple machines, there was still a lot of stuff I didn’t know. Like efficiency, IMA, AMA, and stuff like that. And like for Shock Value, where you have this knowledge portion where you have to take a test, but there’s also an application part. So I just didn’t learn facts, I learned how to apply them.

The depth of learning was commented on,

> All of us probably knew a little about our events beforehand, but we went way in depth, most of us have college textbooks we’re studying from. So it’s not only hard, but it’s in detail, like the details about the different moons, and the water, and I’m sure for everybody else like the electricity, and genetics, and all that stuff.

And another student noted the change in his/her thinking,

> I think Science Olympiad gives you an opportunity to learn a lot more about science. Once you start studying more about science, even though it’s one part of science, like I studied anatomy for Disease Detectives, but even though you start there, you understand the whole concept of science a little more because you studied that one part of science a lot. Because you start thinking in a way that everything makes sense more.

Some of the students also indicated that Science Olympiad made science fun (n = 9), broadened their concept of science (n = 7), and that they learned a lot about science (n = 11). While the students weren’t asked explicitly about their interest in pursuing STEM coursework in the future, their positive attitudes toward science learning may increase the likelihood of their pursuing continued STEM coursework in the future.
Based on the focus group data, cohort participation in science competitions increased student interest in STEM subjects and careers. However, there are distinct differences between the science fair and Science Olympiad groups. While the majority of science fair students who answered the question reported that their participation was a positive influence on their desire to pursue a career in science, there was a group of students who reported that their participation made it less likely that they would become scientists, based on their perceptions of its difficulty and stress level. The Science Olympiad students were much more positive in their assessment of their desire to become scientists and were more likely to credit their participation in Science Olympiad as a positive influence on their desire. In addition, a majority of the Science Olympiad students expressed enthusiasm about science learning. Based on the qualitative data, Research Question 2, that science competition participation increases interest in STEM careers and courses, was supported. There are differences between the two groups in their attitudes toward STEM courses and careers, which supports Research Question 4. Science Olympiad students were more likely than science fair students to express interest in STEM careers and courses, and were likely to credit their experience as a member of a Science Olympiad team as an influence on their interest.

Themes Relating to Student Attitudes
Science Fair Students’ Favorite Part of the Project

Science fair students were asked about their favorite part of the science fair experience. A summary of their responses is in Table 13.

Table 13
*Favorite Part of the Science Fair Process*

<table>
<thead>
<tr>
<th>Component</th>
<th>Number of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doing background research</td>
<td>5</td>
</tr>
<tr>
<td>Conducting the experiment</td>
<td>12</td>
</tr>
<tr>
<td>Making the presentation board</td>
<td>8</td>
</tr>
<tr>
<td>Presenting</td>
<td>13</td>
</tr>
</tbody>
</table>

Students’ comments about the background research focused on their learning of science content. For example, “because of all the things that I did, what I didn’t think that science would do was the effects of skin health. But when I read through the articles, it got really cool. I really found it interesting.” Students who indicated that they liked the experiment the best often referenced the hands-on aspect or the interaction with their test subjects (if they were testing people). They tended to refer to “the experiment” and “the procedure” interchangeably. Sample comments are, “I like the procedure because I kind of liked hands-on things;,, even though it took a really long time because of the subject of my project, I thought that it was really fun,” “I liked doing the testing because you got to find what different people thought,” “I liked seeing the changes,” and “I just like it because it was the most suspenseful part because you really don’t know what your results are going to be.” Students who reported that the
construction of the presentation board was their favorite part tended to mention the creative aspect of the activity. They saw it as the part of the project onto which they could put their personal stamp. For example, “I like making my board the best because I could design the board any way I wanted as long as I did pretty much everything my teacher told me to do, so it was pretty fun and creative” and “I liked to organize the board how I wanted it. And making sure that everything was precise and how I wanted it.” Students who said that presenting was their favorite part of the project focused on improvements in their presentation skills and in their self-confidence in talking to people. There was also a sense of pride in sharing their accomplishments with others. Student comments included, “One of the key things that I got out of the science fair was like presentation skills,” “I feel like I learned a lot because now I feel like I’m more comfortable talking to people because I was able to talk to a lot of people the night of the science fair,” “Presenting isn’t as scary as it seemed to be,” and “I got to show what I’d learned so far and present it to other people.” One student summarized his/her overall experience with the project,

The part where you test everything, that is the most fun part. Presenting is really nerve wracking, you get nervous. Writing the paper is pretty tedious. It’s hard to do. Now I know if the future when I do a science fair project I’m going to avoid testing people because there are so many variables. You can’t control them all.

It is interesting to note that slightly more than half of the students chose as their favorite part of the project what might be considered the nonscientific part of the experience—making the presentation board and presenting their results. According to the students, these activities were popular because they allowed the students to exercise their creativity and present their work to others.
Teamwork and competition were recurring themes in the conversations with the Science Olympiad students. The teamwork themes were not only working as a whole team but also working on individual events with a partner; teamwork was commented about 46 times (some students commented more than once). Working with a partner was generally seen as a positive. Positive student comments about partners included, “You get to work with a lot of people, and you get to experience new information,” “My favorite part was the practices; you get to learn new things and know your partner better,” and “You have to create resource pages and all that, so if your partner takes some and you take some, it really helps to create those pages.” However, some students noted that working with a partner could be a challenge: “Well, basically you have to be open-minded; basically, it depends on if you get along with that person. But you have to be open to get along with that person,” “You have little control over who your partner is going to be, so it really is like random, but you kind of get this connection, you have support, it’s really cool to have people,” and “Sometimes your partner might annoy you, but you have to be in a good mood about it. You just deal with it for the good of the team.” The idea that individuals and partners need to work together for the good of the team carried over into the students’ comments about the team as a whole. Many students were motivated to do well in order to not let the team down. For example, “The thing you have to remember about Science Olympiad, if you don’t medal, if you didn’t do your part, it’s actually you and your other partner, so really you guys all go down together,” “I had never really been on any other teams other than Science Olympiad, but I liked the teamwork the best,” “It’s really a team composed of individual event partnerships that can work together,” and “My favorite
aspect was, well, it’s a lot of work to be on a Science Olympiad team, and it’s not, oh, second place is fine….So I think my favorite part was honestly, living up to the standard.” One student spoke about the difference between needing science knowledge to be successful, and the ability to work with a partner,

I think in certain aspects, yes, because in those study events and academic events you need to put in time and learn all that stuff, and if you’re not doing that, you’re not going to get a medal in that event, and there are events where it’s not so much science as working together, yet it is kind of science. But like EXPD, one of my events, it is not so much science as working together to make something, but you don’t really need a lot of science information for that one event. It kind of depends on what you’re doing.

Another student commented on the role of partnership in the competition,

I guess that I’m just enjoying the aspect of competing, I mean it’s just you and your partner, if you have one, against the entire [sic], all those other schools. So you just got to try your hardest. I mean, you’re sharing your common knowledge and your passion with other people, and I guess that’s what makes it fun.

Another commented,

To mean I learned that it is more than just studying and buckling down. That’s a huge aspect of it, getting really serious about science, but it’s more of an aspect that you have to cooperate with other people, and you have to be able to know when it’s time to be serious, and you have to know these things. So Science Olympiad is just a really great life lesson.

Several students commented on the interdependence of the contestants, such as,

In my event, Can’t Judge a Powder, my partner and I were solely dependent on each other. He does all of the testing, but he is dependent on me to make sure that I get all the information down in the right, specific, way. I have to make sure that he does all of the correct tests, and that he doesn’t miss anything.

and,
I know that the event I’m in, Crime Busters, is solely dependent on two people. Because he does all the powders, and I do all the other stuff. I don’t know how to do powders, so I would probably fail that. In fairness, he probably knows my stuff too. So it’s two people, so we can both do our part.

For many students (n = 23), the competition was their favorite part of participating in Science Olympiad. For some, it was attending the event: “Going all day and hanging out with your friends and going to the events and hopefully doing well,” “It’s really fun when you go around campus and go to all the classrooms,” and “I really just liked everything about it. Every time you go to a competition, you get like adrenalin thrills; it’s like oh, I can do this.” For others, it was participating in the event:

When you’re at regionals and you’re outside your classroom, and you go in and start, you get really nervous. Then like you go in and you know exactly what to do, it goes by so quickly, and you think through your head, “I spent so long on this, and I can like just do it now, and walk out and feel good about it.” Its like, “Wow! I can’t believe I just did that!”

Several students commented on the medal ceremony:

I think my favorite part was at the competition right before they were giving out the medals; the anxiety of whether you were winning or not was my favorite part. It’s really because you put all your time and effort into this one event, and it comes down to this. So it’s the anxiety that causes lots of stress, but I kind of like it because I can see whether it’s worth it or not.

The attitudes of the students toward the teamwork and competition aspects of Science Olympiad were very positive, and for some students, they were the main reason for participating. From students’ comments, there is evidence that these aspects of Science Olympiad also increased their feelings of self-efficacy improved their attitudes toward STEM subjects, which supports –Research Question 3, that competition participation improved attitudes toward STEM subjects and careers.
Both science fair and Science Olympiad students commented about the hard work involved in their participation in the competitions. However, their attitudes differed. Science Olympiad students who commented about the topic (n = 17) were unanimous in stating that while it was hard work, it was worthwhile. Comments made by students included: “Hard work pays off,” “Everyone on the team, they put in a lot of time and effort to their studies. And when you hear your name called, there’s just the best feeling,” and “Like when we built the boomilever, there were a lot of times we failed, but then we got one to work, and that felt really good.” Other comments about hard work were,

It’s a really cool experience where you have these hands on projects where you can build stuff, you can test your knowledge, but you have to work really hard to get whatever you’re doing to be good. You have to keep working at it. Even if you medal at invitationals, you still have to make it better for regionals.

as well as,

Well Science Olympiad has definitely changed me, because I used to think the year before that Science Olympiad was so much work, and I didn’t want to do it, because I don’t have time for that, I don’t want to do it, and I thought that I would hate it because if was so much work. But now that I’ve joined the team it has changed me because now I know that obviously it is a lot of work, but it’s worth it. The time you spend, the competitions and the award ceremony, the feeling you get when you win a medal, it is really just like awesome. It fills you up with these great emotions, because of all the work, you work so hard, and when you finally win it was all worth it.

One student summed up his/her experience,

I just want to say that Science Olympiad is only as hard as you want it to be. If you want you could blow it off, and just come to practice, but not study. Or not even come to practice. You could still compete in the competition. But you can come to every single practice, you can come to extra practices, you can stay
until nine or ten at night. You can study five or six hours a week. You can still
go to the competition. But I think that you can get a medal either way, it just
depends on your attitude. But if you are the person who comes to every practice
and stays late, and works really hard, you can get more gratification, you get
more out of Science Olympiad. And it’s not just about the medals.

Science fair students were mixed in their comments about the hard-work aspect of the
competition. There were 19 students who indicated that the work was worthwhile. Examples of
student comments are, “A lot was really hard, but it was fun in the end,” “I would say that I
thought that it was a good experience for me, but it was a lot of work that I really didn’t want to
do,” and “Science takes a lot of effort, but it was worth it.” One student commented,

One thing I remember…was that it was a ton of work, and most of the time I
was really disorganized. And I had to redo things a lot. But eventually I kind of
got the hang of it. And it turned out to be more successful than I thought that it
would be.

Negative comments regarding the work involved in a science fair project were made by 15
students. The negative comments centered around the stress they experienced, the time it took
to complete a project, and the perceived difficulty of the tasks. Such comments included, “I
thought that it was really stressful, really time consuming too,” “I think that it was pretty
difficult, and I don’t ever want to do it again,” and “the science fair really stresses you out. It
wasn’t an enjoyable part, I didn’t really like it.” One student commented,

I actually thought that it was going to be more fun than it was. And then I
realized that it is a lot of hard work, a lot of researching, a lot of late nights, and
doing science. I thought that it was going to be more fun. It was a lot of hard
work.

For the science fair students, even some of the more positive comments about the amount of
work required revealed an underlying discomfort: “work I didn’t really want to do” and “it was
more successful than I thought it would be” this discomfort wasn’t reflected in the comments made by the Science Olympiad students. This is another aspect that could be a result of the fundamental difference in the two groups of students—voluntary participation vs. compulsory participation.

Summary of the Qualitative Data

All four research questions were supported by the qualitative data. Students in both types of competitions had the opportunity to improve their understanding of science inquiry, which supported Research Question 1. This improvement was more obvious for science fair students, as evidenced by their descriptions of the process they used to complete their projects. Evidence that Science Olympiad students improved their understanding of science inquiry was also present but less obvious. The comments the students made about the improvements to their devices in the building events and their comments about the increase in their science knowledge support this assertion. Therefore, Research Question 3, that there is a difference between the groups, was supported. However, this difference may be a function of how students came to participate in these events—as either a class assignment or as volunteers. Therefore, the groups may not be comparable.

Based on student comments, both groups experienced a change in attitudes toward STEM careers and courses as a result of their participation in science competitions, which supported Research Question 2. For Science Olympiad students, the experience either increased or confirmed their interest in STEM. This was also the case for many science fair students. However, there was a group of science fair students for whom the experience was
detrimental to their interest in STEM. Therefore, Research Question 4, that there is a difference between the two groups, was supported.

Limitations of the Qualitative Data

The data were collected through focus groups. At four of the schools, the science teacher was in the room as required by school and/or district policy. The presence of the teacher may have affected the students’ responses; individual interviews with the students may have elicited different responses to the questions. However, only one school allowed the researcher to conduct individual interviews. Because individual interviews were only conducted with four students at one school, and their responses were not substantively different from what they said in the focus group, data from individual interviews were not included in this study.

Summary of the Quantitative and Qualitative Data

Based on the quantitative data, the null hypothesis that there was no increase in science-inquiry skills and no difference between the two groups was supported (Research Question 1). However, the qualitative data do not support the null hypothesis. The students in both groups reported an increase in their science inquiry skills as a result of their participation in the competitions. Moreover, there were differences between the two groups, with science fair students providing more obvious evidence of increased inquiry skills through their descriptions of the processes they used to complete their projects. The evidence was less obvious for
Science Olympiad students and took the form of explanations of how they improved their devices in the building events and their descriptions of increased science knowledge. The Middle School Science Inquiry Literacy Test did not reveal these increases in skills or the differences between the groups. Perhaps the format of the test (multiple-choice), the small number of questions (13), or the ability of the students to transfer their knowledge was the issue. Whatever the cause of the difference between the quantitative and the qualitative data, the qualitative data strongly support Research Questions 1 and 3.

Based on the quantitative data, the null hypothesis that there was no difference in attitudes toward STEM courses and careers was supported (Research Question 2). However, the qualitative data do not support the null hypothesis, as at least some members of both groups showed an increase in their favorable attitudes. The quantitative and qualitative data support Research Question 4, that there is a difference in attitudes between the groups. As a group, the science fair students scored lower on the quantitative assessment of attitudes (i.e., Science Opinion Survey) than the Science Olympiad students. The qualitative data showed that while a portion of the science fair students exhibited positive attitudes, there was also a group of students with negative attitudes. There was not a similar negative group among the Science Olympiad students. These differences are probably a reflection of the different populations of students who participate in these activities.

Overall, Research Questions 1 and 3 were not supported by the quantitative data but were supported by the qualitative data. Research Questions 2 and 4 were supported by both the quantitative and qualitative data. By combining quantitative and qualitative research methods in a mixed-method study, it is possible to investigate the research questions more deeply than when using one method alone. In this case, the conclusions for Research Questions 2 and 4 are
stronger than they would have been if the study had been based on one data collection strategy.

For Research Questions 1 and 3, the qualitative data provide important information that would have been missed if only quantitative data had been collected. Further interpretation of the data, as well as implications for student instruction and directions for future research, is discussed in Chapter 5.
CHAPTER 5

DISCUSSION, RECOMMENDATIONS, AND DIRECTIONS FOR FUTURE RESEARCH

Introduction

This study had two purposes. First, it sought to determine whether middle school students increased their understanding of science inquiry as a result of participating in science competitions such as science fairs and Science Olympiad. Second, it examined the influence of participation in science fairs and Science Olympiad on middle school students’ attitudes toward STEM subjects and careers.

This chapter includes a discussion of the research findings, recommendations for student participation in science competitions, and directions for future research.

Discussion of Findings

The conceptual framework for the study described how science competitions such as science fairs and Science Olympiad may contribute to student interest and success in the pursuit of STEM careers. The stated goals of both types competition include improving student science inquiry knowledge and skills as well as increasing interest in STEM careers (Illinois Junior Academy of Science, 2012; Science Olympiad, Inc., 2013). While science inquiry skills are critical to success in STEM careers (Anderson, 2007), having such skills
alone will not ensure that students will aspire to STEM careers. Student interest is also essential. Hidi and Renniger (2006) noted that students are more likely to persist on challenging tasks if they are interested in them, and intrinsic motivation is a key to learning and the transfer of that learning (Bransford, Brown, & Cocking, 2000). The important factors that contribute to student interest in STEM careers are opportunities for hands-on, relevant, real-world experiences (Hazari, et al., 2010; Kanter, 2010). However, skills and interest are not enough to ensure that students will pursue a STEM career; students also need to prepare for such a career through rigorous coursework (University of Illinois, 2012). Engaged students with well-developed science inquiry skills should be well-prepared for such coursework and, consequently, their future careers.

The research questions for this study were designed to address the issues of changes in understanding of science inquiry and attitudes toward STEM coursework and careers as a result of participation in two of the most popular types of science competition. In addition, differences in these parameters between students who participated in science fairs and Science Olympiad were explored.

Discussion and Interpretation: Research Questions 1 and 3

Research Question 1: Does formal science competition participation in middle school promote an increase in the understanding of science inquiry?

Research Question 3: Are there differences in understanding of science inquiry between middle school students who participated in science fair, and those who participated in Science Olympiad?
One of the goals for an educational program for adolescents, according to the Association for Middle Level Education, is giving the students the opportunity to engage in and understand the process of inquiry (AMLE, 2010). While it is generally agreed that one of the purposes of science competitions is to increase student science inquiry skills and understanding (Bellipanni & Lilly, 2003; Illinois Junior Academy of Science, 2012; Science Olympiad, Inc., 2013), student participation alone does not guarantee that this will happen. In addition, assessing science inquiry skills and understanding can be problematic.

On two national assessments of student learning, the National Assessment of Educational Progress and the Trends in International Mathematics and Science Study, only a small number of questions are designated as measuring science inquiry skills (National Center for Education Statistics, 2012b, 2012c). In addition, there are very few assessments that are available and appropriate for use at the classroom level. The Middle School Science Inquiry Literacy Test used in this study is a revision of a high school-level test written by Wenning (2007a, 2007b).

The Middle School Science Inquiry Literacy Test was administered as a pretest early in the science fair process, it was administered to the Science Olympiad students before they had participated in any competitions. The posttest was administered after their respective regional competitions. There were no statistically significant differences in the pretest and posttest scores for the group as a whole. When the data were disaggregated by group, there was no significant difference between the pretest and posttest scores within groups. Therefore, based on the quantitative data for Research Question 1, the null hypothesis that science competitions do not promote an increase in the understanding of science inquiry was confirmed. Research Question 3, as formulated, did not specify
whether the differences between the groups were before or after the competition, or both.

There was a significant difference between the pretest scores of the science fair group and the Science Olympiad group, with the science fair students having a lower score. It is interesting to note that while the pretest and posttest scores for the science fair group were not significantly different, they improved enough so that there was no significant difference between their posttest scores and the Science Olympiad post-test scores. In addition, the analysis of student responses to individual items on the inquiry test showed that the science fair students had more items in which there were gains in the number of students answering correctly (seven) than the Science Olympiad students (two). Based on the quantitative data, mean scores, and item analysis relative to the Middle School Science Inquiry Literacy Test Research Question 3 was confirmed, that there is a difference between the two groups, but it should be noted that the statistically significant difference was only for the pretest scores. These findings provide further evidence that the two groups of students were not comparable.

The science inquiry process has been defined as including several components: asking questions, investigating those questions in a systematic way, engaging in data analysis and interpretation, and sharing results (National Research Council 1996, 2000, 2012). The science inquiry process as currently defined has a long history going back at least 500 years. Francis Bacon (1561-1626) was one of the early philosophers of science. He proposed a systematic investigation of the world where axioms were tested through observation and experimentation (D. Simpson, n.d.). This emphasis on systematic investigation was supported by Bacon’s contemporary, Galileo (1564-1642), whose process was to build an apparatus (the telescope), observe and experiment, and then publish his observations.
Isaac Newton’s (1643-1747) extensive experimentation in optics and classical mechanics was also based on the idea of scientific proof in which observations about the natural world lead to logical conclusions. In addition, Newton firmly grounded his conclusions in mathematics (Bronowski, 1973). Careful observation and experimentation were applied to biology as well, notably by Charles Darwin (1809-1882) in developing his theory of natural selection (Darwin, 1859) and by Gregor Mendel (1822-1884) in his experiments with sweet peas that unraveled the mystery of genetic inheritance (O’Neill, 2013). The key understanding for students is that the scientific method isn’t something that was just made up by teachers but is a way of understanding the world that has been in place for a very long time and has proven its usefulness over and over again. In addition, it needs to be understood, as Carl Sagan (1974) pointed out, that not all scientific statements carry equal weight—it is the quality of the evidence that matters.

While the quantitative data suggest that the students as a whole did not increase their understanding of inquiry, the qualitative data suggests otherwise. As noted in Chapter 4, focus group interviews including both groups of students indicated that they had increased their general science knowledge. In addition, many science fair students provided ample evidence of their science inquiry learning and understanding through their use of appropriate terminology in the descriptions of the design and implementation of their projects and in their analysis of the correctness of their hypotheses. Science Olympiad students also provided evidence of their science inquiry understanding in their descriptions of the processes they used in the building events. Their use of terminology was not as precise as that of the science fair students, but evidence of their use of science inquiry skills
was present in terms of their asking questions and systematically attempting to answer them.

Based on the qualitative data, Research Questions 1 and 3 were both supported. The focus group interviews provided evidence of improved understanding of science inquiry for both groups, using the definitions provided by the National Research Council (1996, 2000, 2012). The understanding of science inquiry by the science fair students was closer to the NRC’s definition, based on their use of terminology and their descriptions of their processes, despite having lower scores on the Middle School Science Inquiry Literacy Test. Conversely, the Science Olympiad students displayed a less formal understanding of science inquiry, in spite of having generally higher scores on the quantitative measure. It is possible that this is a reflection of the structure of the two events. The science fair students performed their tasks within the formal framework of the scientific method as defined by the IJAS (2012) and proceeded step-by-step through each phase from formulating a hypothesis to reaching conclusions based on their data. In contrast, even though it was apparent that the Science Olympiad students applied science inquiry skills to the successful completion of their events and engaged in the steps of the scientific method as defined by the IJAS (2012), it was not explicitly articulated. For example, in the events in which Science Olympiad students built devices, it was clear from their comments that they formed hypotheses regarding the improvement of their devices, but they did not think of these ideas as hypotheses. Therefore, when they were interviewed, they were less likely to use such terminology than the science fair students. A more accurate characterization may be that the understanding of science inquiry by the Science Olympiad students was less formulaic than that of the science fair students.
Regarding the Middle School Science Inquiry Literacy Test, while the results did not reach statistical significance, some differences in the performance of the two groups emerged, particularly in the improved total scores and number of students answering individual items correctly for science fair students, which supports the proposition that the two groups were not equivalent. The Middle School Science Inquiry Literacy Test was designed so that it could be given in about 30 minutes. The brevity of the test may have undermined attempts to achieve statistical significance because with so few items, the range of scores was small. It is also possible that the understandings that the students spoke about in the focus groups did not transfer well to a pencil and paper test. Nonetheless, while the focus group data are more meaningful for evaluating the research questions in this study, the quantitative data were included to provide a data point for future research in this area, namely, capturing the students’ understanding of science inquiry that they can speak about so eloquently, in a multiple choice paper and pencil test. Therefore, based on the focus group interview data, Research Question 1 and 3 were confirmed, the students increased their understanding of science inquiry as a result of their participation in science competitions, and there were differences in their understanding based on whether they participated in a science fair or Science Olympiad.

Discussion and Interpretation: Research Questions 2 and 4

Research Question 2. Does formal science competition participation increase middle school student interest in studying STEM subjects and pursuing STEM careers?
Research Question 4. Are there differences in attitudes toward STEM subjects and careers between middle school students who participated in science fairs, and those who participated in Science Olympiad?

A goal of science competitions is increasing the number of students who choose STEM careers as a result of increasing their interest in science. R. D. Simpson et al. (1994) used the metaphor of the STEM career pipeline, in which the courses students choose in high school determine whether they stay in the pipeline. Riegle-Crumb et al. (2011) and Archer, et al. (2010) found that career aspirations in science were related to the students’ interest and enjoyment of science. While some work has been done to measure Science Olympiad student attitudes toward STEM courses and careers (Wirt, 2011), research about science fair student attitudes has been focused on their attitudes toward the competition itself, rather than toward STEM (Czerniak, 1996; Czerniak & Lumpe, 1996). The Science Opinion Survey (Gibson, 2008; Gibson & Chase, 2002) was administered as a presurvey early in the science fair process and before the Science Olympiad students had participated in any competitions. The postsurvey was administered after their respective regional competitions.

As discussed in Chapter 4, there was no statistically significant difference in the presurvey and postsurvey scores within the groups. Therefore, based on the quantitative data, the null hypothesis for Research Question 2, that there would be no effect on attitudes toward STEM coursework or careers, was confirmed.

For Research Question 4, the null hypothesis was rejected, as there was a statistically significant difference in presurvey and postsurvey scores between the groups, with the science fair students scoring lower (i.e. more negative in attitudes) on both the presurvey
and postsurvey. When the data were disaggregated by school, it was found that two of the science fair schools had scores below the mean, while one was higher than the mean. All of the Science Olympiad schools had attitude scores higher than the mean. It might be expected that the Science Olympiad students would have higher (i.e. more positive) scores than the science fair students because they were volunteers. Even more interesting is the apparent disparity between the attitude and inquiry scores: the school with the highest attitude scores had scores below the mean for the inquiry test. The school with the highest inquiry scores had high, but not the highest, attitude scores. This phenomenon was also noted by Riegle-Crumb et al. (2011), who found that enjoyment of science was not a strong indicator of science achievement but was a strong indicator of science career aspirations.

Based on the disaggregated data, Research Question 4 was still supported, but the evidence suggests that differences in schools may be more striking than the differences between the science fair and Science Olympiad groups as a whole. For example, schools SFC and SOB had attitude scores above the mean and inquiry scores below the mean. However, their demographics were very different: SFC was a parochial school in a small city, and SOB was a suburban school with large minority and low-income populations. Therefore, their scores probably cannot be attributed solely to demographics. The reasons for their scores would be a fruitful area for future study. However, because of small sample sizes and the nonnormal distribution of the data, these data need to be interpreted with caution.

As with Research Question 1, the quantitative data relating to Research Question 2 suggest that the null hypothesis of no effect is confirmed, except that the qualitative focus group data demonstrated a generally positive influence for the group as a whole. However, there was a subset of science fair students who expressed negative attitudes, while the
Science Olympiad students as a group expressed positive attitudes as a result of their participation. It is possible that the scores of these two groups balanced each other to produce the lack of statistical significance of the mean scores for the group as a whole.

Research Question 4 was supported by both the quantitative and qualitative data. The qualitative data from the focus group interviews revealed differences between the two groups of students. While some science fair students indicated an interest in pursuing a science career and the positive influence that doing a science fair project had on their aspirations, there was a subgroup that was negative about both. In fact, some students cited the science fair experience as a reason for their lack of interest in a science career. An example of this type of response is, “I don’t think that I would like to be a scientist because I stressed out over my experiment, more stressed out that any project that I had ever done.” The reasons given for the negative attitudes generally related to the length and complexity of the science fair project and the stress the students experienced. These sentiments were echoed in the work of Czerniak and Lumpe (1996), who reported that students found the science fair to be problematic because of the hard work (as defined by the students in the study) involved.

Science Olympiad students tended to be positive about their experiences. The majority of the students reported that their experiences contributed to their desire to pursue a career in science. However, a subset of students reported that they joined Science Olympiad because they wanted to become a scientist in the first place, and that their participation did not affect their aspirations. Therefore, the differences between the two groups (i.e. science fair and Science Olympiad) may be more of a function of their characteristics (i.e. compulsory for science fair students vs. voluntary participation for Science Olympiad students) than of the competitions themselves. At any rate, comments
made by Science Olympiad students concerning the positive aspects of the activity included that it made science fun, it broadened the scope of science, they learned a lot, and they were able to learn about topics in greater depth than in their regular classes. These attitudes are reflected in the work of other researchers. For example, in a study by McGee-Brown (2004), Science Olympiad students reported an increased enjoyment of science and their science classes as a result of their participation, and students in a study by Abernathy and Vineyard (2001) cited fun and learning new things as their top choices of what made the activity rewarding.

Based on the qualitative data, students generally increased their interest in STEM courses and careers (Research Question 2) as a result of their participation in science fair and Science Olympiad competitions. However, as previously mentioned that there was a subgroup of science fair students for whom this was not the case. In terms of differences between groups, Research Question 4 was supported by both quantitative and qualitative data, with Science Olympiad students being more positive. However, this could be a reflection of the effect of their voluntary vs. the science fair students’ compulsory participation.

**Discussion and Interpretation: Themes Relating to Student Attitudes**

During the focus group interviews, three themes emerged that, while not directly related to the research questions, are important for interpreting the data and framing the recommendations based on the study. These are the science fair students’ favorite parts of their projects, the Science Olympiad students’ opinions about teamwork and competition,
and the perceptions of both groups concerning the work and effort involved in participating in these competitions.

According to the National Research Council (1996, 2000, 2012) one of the key components of the science inquiry process is the sharing of results. In a study by Czerniak and Lumpe (1996), 13% of the respondents listed improving presentation skills as a positive aspect of their science fair experience, while 9% listed presenting in front of people as a negative. In this study, slightly more than half of the science fair students who responded to the question about their favorite part of the project indicated that making the presentation board and/or presenting their work was their favorite. However, in their comments, they focused on the nonscientific aspects of these competitions. Students commented about the opportunity to exercise their creativity in designing the presentation board and the opportunity to improve their speaking skills. A smaller group indicated that doing the background research and/or conducting the experiment was their favorite part of the process. In their comments, students showed that they were engaged in science inquiry in an enjoyable way. These comments supported Research Question 1, that the students improved their science inquiry skills. It is also possible to infer some support for Research Question 2, although it is likely that at least some of the students who enjoyed conducting the experiments already had a positive attitude toward STEM pursuits.

A recurring theme among the Science Olympiad students was the importance of teamwork (both with partners in events as well as the team as a whole) and their enjoyment of competition. In a study conducted by McGee-Brown (2004), teachers, parents, and students saw the opportunity for collaboration as one of the greatest strengths of the program. In addition, parents and teachers found that positive recognition of student effort
was a result of teamwork. In this study, some of the students recognized that working with a partner could be a challenge but that it was worth the effort in order to benefit the team as a whole. Several students noted their enjoyment of working with and getting to know their partners, and some recognized that they were able to accomplish more with a partner than they could by themselves. The AMLE (2010) includes in its goals for an educational program for adolescents, opportunities for students to develop their social skills in order to better work with others. Employers value collaboration and communication skills, as these skills are among the top 10 skills in a Forbes survey of employers (Adams, 2013) and a survey of employers seeking to hire recent college graduates (Association of American Colleges and Universities, 2014, Peter D. Hart Research Associates, Inc., 2006).

There are differing opinions in the literature about whether middle school students should participate in academic competitions. The position of the National Science Teachers Association (1999, 2003) is that the competition aspect of science fairs should be de-emphasized. The research of Czerniak and Lumpe (1996) focused on the damaging aspects of classroom competitions. However, the work of Abernathy and Vineyard (2001), in their study of science fair and Science Olympiad students, found that the science competitions were students’ first choice for academic competitions. Students in these studies cited fun and learning new things as their top reasons for competing. Science Olympiad students in the current study commented about how motivated they were by the competition. The themes of many of the comments centered on the competition as an event to work toward and the satisfaction they felt when, through hard work and preparation, they succeeded at something difficult. The students’ comments regarding the competition aspect of Science Olympiad were generally positive. However, this could be as a result of the attitudes of
students who participate in Science Olympiad, because a student who is not interested in competition would be unlikely to join a team. Given the qualitative findings that many of the Science Olympiad students found the competition and teamwork aspects to be enjoyable and motivating, it is possible to infer that the Science Olympiad competitions improved their science inquiry skills and attitudes toward STEM courses and careers to a greater degree than for the science fair students; this supports all of the research questions.

The so-called hard work involved in competing in a science fair or in Science Olympiad was perceived very differently, depending on the group. The responding Science Olympiad students were unanimous that the hard work (as defined by the students) was worthwhile. Science fair students were divided, with some students finding the workload worthwhile and others indicating it was not. The work of Czerniak and Lumpe (1996) had a similar finding, with 61% of their respondents indicating that a disadvantage of science fair participation was wasted time and 20% indicating hard work as a disadvantage. This finding, once again, highlights the fundamental difference between the two groups: compulsory vs. voluntary participation.

As previously discussed, in the focus groups, students highlighted several issues that do not relate directly to the research questions but deserve consideration. In particular, the students’ attitudes toward competition, teamwork, and effort are key components to be considered along with science inquiry understanding and attitudes toward STEM coursework and careers in formulating recommendations for science fairs and Science Olympiad.
Recommendations

Science Olympiad

One key characteristic of Science Olympiad students is that they are self-selected—they volunteer for this extracurricular activity because of their passion for science. They tend to do very well on the inquiry-skills tests at the beginning and do not show much improvement on the posttests. Students noted that they enjoyed the opportunity for in-depth study of science topics, working with a partner and as a team, and going to competitions. However, for Science Olympiad as a whole, emphasis on science inquiry skills is hit or miss, depending on the event. Even for the more inquiry-oriented events (such as the events in which students build devices), the students are working within very narrow parameters. Overall, Science Olympiad is adult-mediated: at the schools studied, the students tried out for the team, and the adults determined which students made the team, who would be partners, and in which events they would compete (although some coaches did allow minimal choice). Additionally, the criteria for participation and success in the events are clearly defined by adults.

The Science Olympiad should add some events to strengthen the science inquiry aspect and provide an arena for student choice and creativity. A “quasi-science fair” event, in which students can choose a topic to research, question to answer, or problem to solve, with open-ended criteria for success (perhaps defined by the students), would be an important addition to Science Olympiad. Such an addition would be supported by the AMLE (2010), as some of its goals for educational programs for adolescents include addressing big ideas and questions
that may not have one correct answer and allowing students to have a voice in what and how they will learn.

**Science Fair**

In contrast, science fair students are generally required to do the project. Many of the students interviewed were genuinely interested in the results of their projects, and their comments showed that they used science inquiry skills to complete their projects. An important strength of the program is the ability of students to choose their topics and design their experiments, which is supported by the AMLE (2010). However, for many students, engaging in a science fair project causes negative attitudes toward science and science careers. The majority of their negative comments related to the length and complexity of the project. This raises the question of whether the length and complexity of the projects is appropriate for this age group. Another issue is the individual nature of the projects, which also raises a question about age-appropriateness. The pressure to succeed or fail falls solely on the individual, which can be intimidating for some students.

A recommendation for organizers of science fairs is to do smaller, shorter projects and more of them. Engaging in these projects with a partner or a small team would also be beneficial, especially if the competitors were teams rather than individuals. Such a structure would alleviate some of the negative aspects of traditional science fairs as reported by Czerniak and Lumpe (1996) and enhance the development of social skills as supported by the AMLE (2010). This change would still allow students to engage in science inquiry, increase their understanding of science inquiry, and permit them to explore in depth the topic of their
choice, as well as improve their collaboration skills, in a more age-appropriate manner. Students reported that they enjoyed making the presentation board and giving the presentations, so these aspects should be retained. Another recommendation is to include more Science Olympiad-type experiences in regular instruction, such as building events, to give students an opportunity to engage in deep learning of science topics and to work as a team, which are both strengths of Science Olympiad.

Directions for Future Research

This study would have been enhanced by having a better method to quantitatively measure growth in student-inquiry skills. While the qualitative data implied growth, a better way to measure such growth quantitatively is needed. The same is true for the quantitative STEM attitude data. While the surveys uncovered some differences between the groups, the focus group interviews revealed more information. In some cases, the analysis of the quantitative data was not possible because of the small sample sizes. A study with larger sample sizes would be useful for finding connections between the qualitative and quantitative data.

Further research should be conducted to gain a better understanding of the influence of Science Olympiad participation on student-inquiry skills. A closer examination of student experiences in individual events, rather than the competition as a whole, may uncover more information about changes in student-inquiry skills than was apparent in this study.

Another avenue of future research is the effect of modifications to the science fair protocol in relation to decreasing negative student attitudes while maintaining increases in
student science inquiry skills. It would be interesting to find out if shorter, more frequent projects conducted with a partner or small team would be less intimidating for students without sacrificing science inquiry skills.

Finally, if permission could be obtained to conduct individual interviews with the students studied, it is possible that more detailed and candid information could be collected pertaining to all of this study’s research questions.

Significance of the Study

According to the Society for Science and the Public, science plays a key role in the advancement of humanity (Society for Science and the Public, 2014b). The STEM Education Coalition maintains that STEM education is important for the future economic prosperity of the United States and for Americans to be able to compete successfully in the global arena (STEM Education Coalition, 2012). Communication and collaboration skills are valued by employers (Adams, 2013; Association of American Colleges and Universities, 2014; Peter D. Hart Research Associates, 2006). Increasing student understanding of science inquiry and improving their attitudes toward STEM course and careers are important factors in moving toward these goals of advancing humanity, increasing economic prosperity, and improving the collaboration and communication skills that are valuable to employers. Science competitions can be a factor in meeting these goals for students. In this study, participation in science competitions was shown by the qualitative data to increase student science inquiry understanding and attitudes toward STEM courses and careers.
Conclusion

The researcher sometimes mentor young teachers, and when they are puzzled by issues in their classroom, she often counsels them to “ask the kids.” This philosophy of going directly to the source when seeking information was the basis of this study. The purposes of this study were to determine whether science fair and Science Olympiad participation increased student understanding of science inquiry, and whether they increased students’ positive attitudes towards STEM courses and careers. Very little work has been done in this area of such importance, given the number of students who participate, and the time and money spent on these competitions every year. So the researcher asked the kids these questions, both quantitatively and qualitatively, and they answered. Both types of competitions have value for improving science inquiry understanding and increasing positive attitudes toward STEM courses and careers. However, neither competition is perfect. With relatively little effort, each competition could be modified by adding some of the best qualities of the other competition to better meet the needs of the students. The teamwork of Science Olympiad and the student choice in developing a project of science fairs are two of these key characteristics. Perhaps the two competitions could be combined to create a new competitions, a “Science Fair Olympiad,” that would better serve the students of the 21st century.
REFERENCES


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APPENDIX A

NORTHERN ILLINOIS UNIVERSITY OFFICE OF RESEARCH COMPLIANCE AND INTEGRITY APPROVAL
March 27, 2013

MEMORANDUM

TO: Kathleen Schmidt
   Department of Literacy Education

FR: Christopher P. Parker, Vice Chair
    Institutional Review Board #1

RE: Graduate student research involving the use of human subjects for the project titled Science fairs and science Olympiad: Influence on student science inquiry learning and interest in STEM related coursework and careers

This is to inform you that the above-named application for human subjects research has been approved by Subcommittee Review. The rationale for expedited review is section 45 CFR 46.110 and 21 CFR 56.110, Categories 6 & 7. Although you may begin data collection immediately, please be advised that federal regulations require that the Institutional Review Board (IRB) be made aware of all research activities that place human subjects at maximum or minimum risk. Your application will be brought to the attention of the IRB at its next meeting. This approval is effective for one year from the date of this letter.

Unless you have been approved for a waiver of the written signature of informed consent, I have enclosed a date-stamped copy of the approved consent form for your use. NIU policy requires that informed consent documents given to subjects participating in non-exempt research bear the approval stamp of the NIU IRB. This stamped document is the only consent form that may be photocopied for distribution to study participants. If your project will continue beyond that date, or if you intend to make modifications to the study, you will need additional approval and should contact the Office of Research Compliance for assistance. Continuing review of the project, conducted at least annually, will be necessary until you no longer retain any identifiers that could link the subjects to the data collected.

It is important for you to note that as a research investigator involved with human subjects, you are responsible for ensuring that this project has current IRB approval at all times, and for retaining the signed consent forms obtained from your subjects for a minimum of three years after the study is concluded. If consent for the study is being given by proxy (guardian, etc.), it is your responsibility to document the authority of that person to consent for the subject. Also, the committee recommends that you include an acknowledgment by the subject, or the subject's representative, that he or she has received a copy of the consent form. In addition, you are required to promptly report to the IRB any injuries or other unanticipated problems or risks to subjects and others. Please accept my best wishes for success in your research endeavors.

CPP

cc: E. Shin
    P. Kelber
    C. Law (grad school)
    Institutional Review Board members
    ORC #HS13-0097
Approval Notice
Protocol Amendment

23-Sep-2013
Kathleen Schmidt
Literacy Education

RE: Protocol # HS13-0097 “Science fairs and science olympiad: Influence on student science inquiry learning and interest in STEM related coursework and careers”

Dear Kathleen Schmidt,

Your Protocol Amendment submission was reviewed and approved under Expedited procedures by Institutional Review Board #1 on 23-Sep-2013.

Please note the following information about your approved research protocol:

If your project will continue beyond that date, or if you intend to make modifications to the study, you will need additional approval and should contact the Office of Research Compliance and Integrity for assistance. Annual review of the project will be necessary until you no longer retain any identifiers that could link the subjects to the data collected.

It is important for you to note that as a research investigator involved with human subjects, you are responsible for ensuring that the project has current IRB approval at all times, and for retaining any signed consent forms obtained from your subjects in a secure place for a minimum of three years after the study is concluded. The committee also recommends that the informed consent include an acknowledgement that the subject, or the subject's representative, that he or she has received a copy of the consent form. In addition, you are required to promptly report to the IRB any injuries or other unanticipated problems involving risks to subjects or others.

Please remember to use your protocol number (HS13-0097) on any documents or correspondence with the IRB concerning your research protocol.

We wish you the best as you conduct your research. If you have any questions or need further help, please contact the Office of Research Compliance and Integrity at (815) 753-8588.

http://northernillinois.edu/global/compliance/ShowPDF.cfm?document=561A8B5E-902E-484D-84E4-05DC9300D628
Approval Notice
Continuing Review

13-Mar-2014
Kathleen Schmidt
Literacy and Elementary Education

RE: Protocol # HS13-0097 “Science fairs and science olympiad: Influence on student science inquiry learning and interest in STEM related coursework and careers”

Dear Kathleen Schmidt,

Your Continuing Review submission was reviewed and approved under Expedited procedures by Institutional Review Board #1 on 07-Mar-2014.

Please note the following information about your approved research protocol:


Please remember to use your protocol number (HS13-0097) on any documents or correspondence with the IRB concerning your research protocol.

If you are still recruiting subjects and have not waived the written signature of consent, I have attached a date-stamped copy of the approved consent form for your use. NIU policy requires that informed consent documents given to subjects participating in non-exempt research bear the approval stamp of the NIU IRB. This stamped document is the only consent form that may be photocopied for distribution to study participants. If your project will continue beyond that date, or if you intend to make modifications to the study, you will need additional approval and should contact the Office of Research Compliance and Integrity for assistance.

Continuing review of the project, conducted at least annually, will be necessary until you no longer retain any identifiers that could link the subjects to the data collected.

It is important for you to note that as a research investigator involved with human subjects, you are responsible for ensuring that this project has current IRB approval at all times, and for retaining the signed consent forms obtained from your subjects in a secure place for a minimum of three years after the study is concluded. If consent to participate is being given by proxy (guardian, etc.), it is your responsibility to document the authority of that person to consent for the subject. In addition, you are required to promptly report to the IRB any injuries or other unanticipated problems involving risks to subjects and others. Please accept my best wishes for success in your research endeavors. If you have any questions or need further help, please contact the Office of Research Compliance and Integrity at (815) 753-8588.
APPENDIX B

BASIC COURSE IN THE PROTECTION OF HUMAN SUBJECTS CERTIFICATE
UNIVERSITY OF MIAMI LEONARD M. MILLER SCHOOL OF MEDICINE

certifies that

Kathleen Schmidt, MAT

has participated in the educational activity titled

CITI Basic Course in the Protection of Human Research Subjects

on

2/9/2013

This activity was designated for 6.00 AMA PRA Category 1 Credits™.

University of Miami Leonard M. Miller School of Medicine is accredited by the Accreditation Council for Continuing Medical Education to provide continuing medical education for physicians.

University of Miami Leonard M. Miller School of Medicine designates this enduring material for a maximum of 6.00 AMA PRA Category 1 Credits™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Oscar Reyes
Director of Continuing Medical Education
September 9, 2013

You are invited to participate in a research study titled "Science Fairs and Science Olympiad: Influence on Student Science Inquiry Learning and Interest in STEM Related Coursework and Careers."

Why do this study? Why do this study? The purpose of the study is to find out if students who participate in science competitions increase their science inquiry skills and improve their attitudes towards studying or pursuing a career in science, technology, engineering, or mathematics.

Your participation in this study will include administering the Science Opinion Survey and the Science Inquiry Literacy Test during class time, or during regularly scheduled Science Olympiad meetings, before and after the science competition, and assisting the researcher with obtaining parent permissions and scheduling focus group interviews and individual interviews either during class time or during the lunch period. The children’s responses to the Science Opinion Survey and Science Inquiry Literacy Test, as well as their responses during the focus group and interview sessions should not affect any future instruction that they receive.

Are there any risks? There are no risks. Although Northern Illinois policy does not provide for compensation for treatment of any injuries that may result from participation in research activities, this should not be construed as a waiver of any legal rights or redress you might have as a result of participation in this study.

How will you benefit from this? The benefits you may personally receive from participating in this study are to learn about the effects of science competitions on student skills and attitudes.
Are my answers confidential? Information obtained during this study may be published in scientific journals or presented at scientific meetings. However, there will not be any information that could identify you or your students.

Participation in this study is voluntary. You may withdraw from participation at any time without penalty or prejudice.

Whom do I call if I have questions? Any questions about the study should be addressed to me via e-mail, at schmidt1345@sbcglobal.net or phone at (630) 858-4206. You may also contact my dissertation advisor, Dr. Paul Kelter at pkelter@niu.edu, or phone, at (815) 752-0327.

If you wish further information regarding your rights as a research subject, you may contact the Office of Research Compliance at Northern Illinois University at (815) 753-8588.

Sincerely,

Kathleen Schmidt
Doctoral Student, Department of Literacy Education

I agree to participate in this research study and acknowledge that I have received a copy of this consent form.

__________________________  __________________________
Signature of Teacher        Date

APPROVED
MAR 27 2013
BY NUL LUL
VOID ONE YEAR
FROM ABOVE DATE
September 9, 2013

I seek your permission to have (Teacher’s name and class) participate in a research study titled “Science Fairs and Science Olympiad: Influence on Student Science Inquiry Learning and Interest in STEM Related Coursework and Careers.”

Why do this study? Why do this study? The purpose of the study is to find out if students who participate in science competitions increase their science inquiry skills and improve their attitudes towards studying or pursuing a career in science, technology, engineering, or mathematics.

I seek your permission to meet with the participating teacher(s) for 1 hour outside of the normal school day to discuss the project and the implementation of the lessons for their students. The in-class participation of students in this study will last for 1 class period prior to the science competition, and 1 class period after the competition. The teacher will also assist the researcher with scheduling focus group interviews and individual interviews during class time, during the lunch period, or during regularly scheduled Science Olympiad meetings.

Are there any risks? There are no risks. Although Northern Illinois policy does not provide for compensation for treatment of any injuries that may result from participation in research activities, this should not be construed as a waiver of any legal rights or redress each child might have as a result of participation in this study.

How will students benefit from this? The benefits students may personally receive from participating in this study may include an awareness of his/her interest in science, technology, engineering, and mathematics courses or careers.

Are all assessment tool answers confidential? Information obtained during this study may be published in scientific journals or presented at scientific meetings. However, there will not be any information that could identify any student or teacher.
Does each child have to complete the questionnaires or allow her or his answers to be used in the study? Participation in this study is voluntary. The parent/guardian decision about participation of the child, as well as his or her assent to participate will not negatively the child. The child will be asked to indicate individual assent to be involved immediately prior to participation, and will be free to withdraw from participation at any time without penalty or prejudice. The child’s responses on the Science Opinion Survey, the Science Inquiry Literacy Test, and during the focus groups and interviews will not affect the child’s future instruction.

Whom do I call if I have questions? Any questions about the study should be addressed to me via e-mail, at schmidt1345@sbcglobal.net or phone at (630) 858-4206. You may also contact my dissertation advisor, Dr. Paul Kelter at pkelter@niu.edu, or phone, at (815) 752-0327.

If you wish further information regarding the child’s rights as a research subject, you may contact the Office of Research Compliance at Northern Illinois University at (815) 753-8588.

Sincerely,

Kathleen Schmidt
Doctoral Student, Department of Literacy Education

I agree to allow my teacher(s) and students to participate in this research study and acknowledge that I have received a copy of this consent form.

Signature of Principal

Date

APPROVED

MAR 27 2013

BY NUIRRL

VCCD ONE YEAR

FROM ABOVE DATE
Appendix B: Consent Materials

Northern Illinois University

Your child/ward is invited to participate in a research study titled "Science Fairs and Science Olympiad: Influence on Student Science Inquiry Learning and Interest in STEM Related Coursework and Careers."

Why do this study? The purpose of the study is to find out if students who participate in science competitions increase their science inquiry skills and improve their attitudes towards studying or pursuing a career in science, technology, engineering, or mathematics.

Your child's/ward's participation in this study be to take a Science Opinion Survey and a Science Inquiry Literacy Test during class time before and after the competition, which should take about 45 minutes each time, for a total of 90 minutes. Your child will also be invited to participate in a 30 minute focus group session and a 30 minute individual interview after the competition. The focus groups and interviews may take place during class time, during the lunch period, or during a regularly scheduled Science Olympiad meeting. Participation in any or all of the activities is completely voluntary. Your child's responses on the Science Opinion Survey, the Science Inquiry Literacy Test, during the focus group, or during the interview will not affect any future instruction that your child will receive. If you would like to review the Science Opinion Survey, the Science Inquiry Literacy Test, or the focus group questions, please contact me at schmidt1345@sbcglobal.net or (630) 858-4206.

Are there any risks? There are no risks. Although Northern Illinois policy does not provide for compensation for treatment of any injuries that may result from participation in research activities, this should not be construed as a waiver of any legal rights or redress you or your child/ward might have as a result of participation in this study.

How will my child benefit from this? The benefits your child/ward may personally receive from participating in this study may include an awareness of his/her interest in science, technology, engineering, and mathematics courses or careers.
Are my answers and my child's/ward's answers confidential? Information obtained during this study may be published in scientific journals or presented at scientific meetings. However, there will not be any information that could identify your child/ward.

Does my child/ward have to complete the questionnaires or allow her or his answers to be used in the study? Participation in this study is voluntary. Your decision whether or not to allow your child/ward, as well as his or her assent to participate will not negatively affect you or your child/ward. Your child/ward will be asked to indicate individual assent to be involved immediately prior to participation, and will be free to withdraw from participation at any time without penalty or prejudice.

Whom do I call if I have questions? Any questions about the study should be addressed to me via e-mail, at schmidt145@sheglobal.net or phone at (630) 858-4206. You may also contact my dissertation advisor, Dr. Paul Kelter at pkelter@niu.edu, or phone, at (815) 752-0327.

If you wish further information regarding your rights or your child's/ward's rights as a research subject, you may contact the Office of Research Compliance at Northern Illinois University at (815) 753-8688.

Sincerely,

Kathleen Schmidt
Doctoral Student, Literacy Education

I agree to allow my child/ward, ______________________ to participate in this research study and acknowledge that I have received a copy of this consent form.

Signature of Parent/Guardian ______________________ Date ____________

APPROVED
MAR 3 7 2013
 void one year from above date
I agree to help Mrs. Schmidt with her research study called "Science Fairs and Science Olympiad: Influence on Student Science Inquiry Learning and Interest in STEM Related Coursework and Careers." She told me that the reason for the study is to find out whether participating in a science competition affects my ideas about science and science careers.

I understand that if I help with this study, I will be asked to take a survey and a test before and after the competition. I can also volunteer to be part of a focus group and/or an interview with Mrs. Schmidt.

I know that I can quit anytime without any problem and that I don't need to answer questions that I don't want to answer.

I know that if I do the activities and answer questions, Mrs. Schmidt will only use the answers in her study if my parents and I say it is OK.

I know that everything I tell Mrs. Schmidt will be kept confidential. That means that she won't use my name or let people know that I'm the one who said the things I said. I do understand that if I take part in a focus group, there is no guarantee that the other students will not talk about what has been said.

Minor's Name (Please print) __________________________ Age __________________________

Signature of Minor Participant __________________________ Date __________________________

I understand that the focus group and interviews will be audiotaped.

Signature of minor participant __________________________ Date __________________________
I agree to help Mrs. Schmidt with her research study called "Science Fairs and Science Olympiad: Influence on Student Science Inquiry Learning and Interest in STEM Related Coursework and Careers." She told me that the reason for the study is to find out whether participating in a science competition affects my ideas about science and science careers.

I understand that if I help with this study, I will be asked take a survey and a test during class time before and after the competition. I can also volunteer to be part of a focus group and/or an interview with Mrs. Schmidt during class time or during lunch.

I know that I can quit anytime without any problem and that I don’t need to answer questions that I don’t want to answer.

I know that if I do the activities and answer questions, Mrs. Schmidt will only use the answers in her study if my parents and I say it is OK.

I know that everything I tell Mrs. Schmidt will be kept confidential. That means that she won’t use my name or let people know that I’m the one who said the things I said. My answers on the survey and test, and what I say during a focus group or interview will not affect my grade or what I do in class. I do understand that if I take part in a focus group, there is no guarantee that the other students will not talk about what has been said.

______________________________________________________________________________
Minor’s Name (Please print) Age

______________________________________________________________________________
Signature of Minor Participant Date

APPROVED
MAR 27 2013
BY N.J.L.S.
VOID ONE YEAR FROM ABOVE DATE
APPENDIX D

MIDDLE SCHOOL SCIENCE INQUIRY LITERACY TEST
Directions: Choose the best answer for each question.

1. A scientist wants to explain why something happens in a certain way. Decide which order the following should be done in a scientific experiment that might help to provide an answer:

   R. Draw a conclusion about the preliminary explanation or hypothesis
   S. Make a prediction
   T. Conduct an experiment
   U. Develop a preliminary explanation or hypothesis

   a. S, T, R, U
   b. R, T, U, S
   c. U, S, T, R
   d. T, U, S, R

2. A farmer wants to know if one fertilizer is better than another. The farmer plants soybeans in two fields located 3 miles apart. Brand X fertilizer is used in a field in an open area, and Brand Y fertilizer used in a field that is surrounded by a forest. What, if anything, is the biggest problem with the experiment’s design?

   a. Nothing; the design is fine.
   b. The design does not control all of the variables that might affect the results of the experiment.
   c. The plots are so close together that the fertilizers might get mixed.
   d. The fertilizers might be mixed if they are sprayed on the plots.

3. How might the design of the above experiment be improved, if at all?

   a. The experiment does not need to be improved.
   b. Select plots that are closer together than 3 miles.
   c. Apply Brand X and Brand Y to separate halves of both fields.
   d. During year 2, use Brand Y on Plot #1 and Brand X on Plot #2 and average the results.

4. A scientist wants to test a medicine to see how well it works to cure a disease. She has 25 volunteers who have the disease take the medicine, and after two weeks, the disease disappears. What, if anything, is wrong with the experimental design?

   a. Nothing, the experiment was done correctly, and the medicine was proven to work.
   b. This sort of experiment should never be done with volunteers because it might influence the results.
   c. The scientist did not wait long enough to see if the disease would come back.
   d. There was no control group.
5. A person has a flashlight that doesn’t work, and wants to fix it. In order to fix it, the person needs to describe what they think is wrong with the flashlight, and then come up with a way to test their ideas. Which of the following statements would provide the best explanation that the person could use to develop an experiment to find out why the flashlight doesn’t work?

   a. The flashlight has dead batteries.
   b. The flashlight is old.
   c. The flashlight’s lens cover is missing.
   d. The flashlight’s body is made of metal.

6. A science teacher takes 2 cylinders that appear to be identical except that one is colored red, and the other is blue. He drops the cylinders at the same time from the same height. They hit the floor at the same time—a fraction of a second later. The teacher then drops the red cylinder through a tube that is not magnetic and it hits the ground in a fraction of a second. He then drops the blue cylinder through the tube, and hits the ground 5 seconds later. The students are very surprised, and want to know what happened. The teacher repeats the demonstration several more times with the same results. Which if the following would be the best question to ask to start a scientific investigation of what is happening?

   e. How do the red and blue cylinders differ?
   f. What effect does color have on the speed of the fall?
   g. What are the weights of the red and blue cylinders?
   h. What is the tube made of?

7. A scientist wants to sample the height of bamboo plants are growing in a tropical rain forest. To make it easy to collect data, the scientist randomly measures plants around the edge of the forest. Is this a good way to collect data? Why or why not?

   a. Yes, as long as the sample is random it will give a good average of the forest as a whole.
   b. Yes, it is difficult to travel in a rain forest, sampling just along the edge is fine.
   c. No, the sample is only from the edge, so the sample does not represent plants from the whole forest.
   d. No, every plant in the forest must be measured.
8. A concerned citizen uses a web page written by the nuclear power industry to find out what the arguments are against the construction of a nuclear power plant. Is this a valid way to find out about these arguments?

   a. Yes, the nuclear power industry is regulated by the U.S. government to ensure fair and honest dealings with the public.
   b. Yes, there are “watchdog” agencies and “bloggers” to make sure that they are telling the truth.
   c. No, the nuclear power industry might be biased and may not accurately write about arguments against nuclear power.
   d. No, the nuclear power industry will not be aware of the arguments against them.

9. Middle school students at a small school surrounded by farms want to find out how the people in their area feel about building a wind farm nearby. Which would be the best way to find a reliable answer to the question?

   a. Stop adults at a local shopping mall and ask them to fill out a survey.
   b. Randomly select 10% of the people in the area and send them a survey.
   c. Go to every house in the area and ask them what they think about the wind farm.
   d. Ask experts and scientists what they think about the wind farm.

10. During autumn, a scientist sees that bears hibernate, birds fly south, and leaves change color. The scientist decides that winter is caused by bears hibernating, birds flying south, and leaves turning color. Do you agree or disagree with the scientist, and why or why not?

    a. Agree, these events happen every autumn, just before winter.
    b. Agree, all of these events contribute to the cooling that brings about winter.
    c. Disagree, winter is caused by the Earth moving farther from the sun.
    d. Disagree, just because an event occurs before another, it does not mean that the first event causes the second.

11. A shopper goes to the store to buy oranges. Not knowing which type is the sweetest, he buys three varieties. These are the results:

<table>
<thead>
<tr>
<th>Color</th>
<th>Size</th>
<th>Sweetness</th>
<th>Price/orange (cents)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark orange</td>
<td>Medium</td>
<td>Somewhat sweet</td>
<td>43</td>
</tr>
<tr>
<td>Medium orange</td>
<td>Small</td>
<td>Very sweet</td>
<td>19</td>
</tr>
<tr>
<td>Light orange</td>
<td>Large</td>
<td>Not sweet</td>
<td>30</td>
</tr>
</tbody>
</table>

Which of the following is correct conclusion about the sweetness of these oranges?

   a. The darker the color of the orange, the sweeter it is.
   b. The larger the orange, the sweeter it is.
   c. The more expensive the orange, the sweeter it is.
   d. None of the above conclusions about sweetness is correct.
12. Students notice that a tree outside their classroom is losing its leaves. They wonder about the cause. They note that the custodian waters the grass three times per week, and that water collects in a pool around the base of the tree. What would be the most reasonable explanation for the cause of the loss of the tree’s leaves?

   e. The grass around the tree is being over watered.
   f. The tree is losing leaves from too much water.
   g. The tree is dying from old age.
   h. A recent cold spell killed the leaves.

13. A student wants to measure reaction time. He has another student drop a meter stick, and he catches it between his thumb and index finger. The experiment is repeated 5 times. The mark where he catches it each time is recorded. The student catches the meter stick at the 73cm, 68cm, 81cm, 75cm, and 78cm marks. What is the most likely reason that the student repeated the experiment 5 times, rather than just doing it once?

   a. The human reaction time is not zero, as the experiment clearly shows.
   b. The student needed more data to make the distance fit his prediction.
   c. An average distance is more representative that a single distance.
   d. There is always error in reading a stopwatch.
APPENDIX E

SCIENCE OPINION SURVEY
Science Opinion Survey

Read each statement. Circle the letter that most closely matches your opinion of the statement. There are no right or wrong answers—we just want your opinion.

<table>
<thead>
<tr>
<th></th>
<th>I strongly agree</th>
<th>I agree</th>
<th>I am not sure</th>
<th>I disagree</th>
<th>I strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Science lessons are fun</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2.</td>
<td>I would dislike being a scientist after I leave school</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3.</td>
<td>I would like to take another science course</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4.</td>
<td>I dislike science lessons</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5.</td>
<td>When I leave school, I would like to work with people who make discoveries in science</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6.</td>
<td>I will be glad when I am done taking science classes</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7.</td>
<td>School should have more science lessons each week</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>8.</td>
<td>I would like a job in a science laboratory when I leave school</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9.</td>
<td>I would like to learn more about science</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10.</td>
<td>Science lessons bore me</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>11.</td>
<td>Working in a science laboratory would be an interesting way to earn a living</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>12.</td>
<td>I would be wasting my time if I took more science courses</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>13.</td>
<td>Science is one of the most interesting school subjects</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>14.</td>
<td>A career in science would be dull and boring</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>15.</td>
<td>I will miss taking science courses in the future</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>16.</td>
<td>Science lessons are a waste of time</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>17.</td>
<td>I would like to teach science when I leave school</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>18.</td>
<td>I do not want to take any more science classes</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>19.</td>
<td>I really enjoy going to science lessons</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>---</td>
<td>---------------------------------------------------------------------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>20</td>
<td>A job as a scientist would be boring</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Additional science courses are not a waste of time</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>22</td>
<td>The material covered in science lessons is uninteresting</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>23</td>
<td>A job as a scientist would be interesting</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>24</td>
<td>Science courses I take in the future will be boring</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>25</td>
<td>I look forward to science lessons</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>26</td>
<td>I would dislike becoming a scientist because it takes too much education</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>27</td>
<td>Science classes I take in the future will be interesting</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>28</td>
<td>I would enjoy school more if there were no science lessons</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>29</td>
<td>I would like to be a scientist when I leave school</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>30</td>
<td>I do not need to learn more science</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
APPENDIX F

PERMISSION TO USE THE SCIENCE INQUIRY LITERACY TEST
Re: ScInqLiT
From: Carl Wenning <wenning@phy.ilstu.edu>
Add to Contacts
To: Kathleen Schmidt <schmidt1345@sbglobal.net>

Hi Kathy,

You are welcome to use ScInqLiT if it meets your needs.

Here is the background article:

http://www.phy.ilstu.edu/pte/publications/assessing_ScInq.pdf

Here is the test:

The test is password protected. The password is:

Enjoy!

Carl

--
Dr. Carl J. Wenning
Department of Physics
Illinois State University
Normal, IL 61790-4560
wenning@phy.ilstu.edu
(309) 830-4085 (cell)

From: Kathleen Schmidt <schmidt1345@sbglobal.net>
Date: Thursday, November 15, 2012 7:46 PM