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A Mixed Methods Study of the Relationships among Academic Achievement, Teaching Strategies and Science and Engineering Fair Participation

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By

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It has long been accepted by science education research that science inquiry in the classroom is essential to the development of a deep understanding of the nature of science and the world around us. In an effort to understand the relationship between science inquiry, science process skills, the nature of science and science and engineering fairs, this mixed methods study qualitatively explores teaching strategies of exemplary science and engineering teachers (*N=6*) who mentored several International Science and Engineering Fair finalists within a 10 year period (2004-2014). The quantitative portion of this research explored the relationship between science fair participation and academic achievement. Using the theoretical framework of modern expectancy-value theory, 5 themes emerged. All believed: 1) there is intrinsic value in science inquiry and science fair; 2) all included strategic engagement opportunities for students; 3) intrinsic value and motivation potentially lead to increased academic aptitude; 4) the benefits of science inquiry and science fair outweigh costs; and 5) there is a link between intrinsic value in science and engineering fair and utility value. Of the schools *(N=31*) identified for the quantitative study, demographic analysis (gender, ethnicity, socio-economic statics, and

size of school) narrowed to 8 treatment schools with one control school indicated no statistical relationship between academic performance on a standardized state science examination and science fair participation. An ad hoc study indicated the standardized testing instrument was not an adequate measurement of the level of inquiry included in a science and engineering fair project. In conclusion, a list comprised of exemplary science and engineering fair suggestions was formulated to include descriptions of similar teaching strategies or issues among the exemplary science and engineering fair teachers with intentions of increasing science inquiry or the nature of science in the classroom through the science and engineering fair framework.

DEDICATION

First and foremost, I would like to dedicate this dissertation to my wonderful savior, Jesus Christ; for without him, how lost I would be. Secondly, I would like to dedicate this dissertation to my late father, Thomas Joshua Hazlett, Sr. His words of wisdom, encouragement, constructive criticism and support have echoed through my mind as I rose to the challenge of obtaining a Ph.D.

Mostly, I would like to dedicate this dissertation to the greatest earthly influence on my life, my loving husband, Dr. Christopher D. McDaniel. He has been my support, confidant, mentor and fanatic cheerleader. He has made the bumpy road smooth and the smooth roads a joy. Without him, I could not have treaded this path successfully. Also, I dedicate this dissertation to the two treasured blessings of my life, my daughters Morgan and Megan. I also dedicate this dissertation to the woman who is my greatest role model, my mother Betty Hazlett. Her courage and determination have been a shining example for me. Lastly, I would like to dedicate this dissertation to my in-laws Peggy and Perry McDaniel, whose undying support and love continue to be a true blessing in my life.

It is my belief that a person's success is not only measured by the fruits they bare outwardly, but the support and love that surrounds them. I am truly blessed to have my family, husband, daughters, mother and in-laws who have been my beacon of support, motivation and object of strength throughout this dissertation process. I am eternally grateful for their patience, love and support.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Trends of Science Inquiry in Education

Science inquiry, defined as the use of knowledge, imagination, reasoning, and process skills to actively develop science understanding and investigation of the world around us, is a common focus in science curricula (DeBoer, 1991). In the past, teachers have supplemented science inquiry instruction to include hands-on research based projects, such as the science and engineering projects that engage students in a deeper learning experience. Bellapani and Lilly (1999) suggested that science and engineering fair projects can be "instrumental in making science make sense to students who may otherwise miss the opportunity to learn more about the world in which they live" (p. 49). This research seeks to explore the teaching methodologies and incorporation of science process skills through the platform of successful or exemplary science and engineering teacher mentors.

Historically, Armstrong's (1989) heuristic learning, Spencer's discovery science (as cited by DeBoer, 1991), and Dewey's (1910) "science is…a way…of thinking and knowing" (p. 121-122) approaches to science inquiry encouraged students to think abstractly and develop deep thinking processes. Specifically, Dewey (as cited by Warde, 1960) suggested a growing need for students to develop project-based learning. This teaching methodology provides students opportunities to engage in discovery, comparing

and analyzing results, self-reliance and cooperative behavior. Currently, with the influence of educational reforms such as Next Generation Science Standards (NGSS Lead States, 2013) and Common Core State Standards (Common Core Standards Initiative, 2017) or College and Career Readiness Standards (CCRS, 2016), state science curricula restructuring has once again included an attempted increase in the emphasis of science inquiry through crosscutting concepts of science content and engineering practices which are considered essential for all students in grades kindergarten through twelfth grade (NGSS Lead States, 2013; Shope & McComas, 2015).

The United States has long been touted as a leader in the global economy. However, the United States is falling behind in its educational rankings. Reis (2015) reported that the United States "ranks first in innovation, seventh in availability of the latest technologies, first in university-industry collaboration on [research and development], and fourth in the quality of its scientific research institutions" (p. 33). The 2011 as well as 2015 Trends in International Mathematics and Science Study (TIMSS) indicated that the science achievement scores for fourth and eighth grade are higher than the international TIMSS scale average, top 10 in fourth grade and top 23 in eighth grade. However, from 1997-2011 there was no measureable difference between the U.S. Average science score at Grade 4 or Grade 8. This further suggested that the United States is not declining in international educational rankings, but is not improving. Reis, Dionne, & Trudel (2015) also reported that The Level Playing Field Institute (2014) ranked United States 52nd among 139 nations in the quality of mathematics and science instruction. As indicated by Christiansen, Kuure & Lindstrom (2013) previous

educational standards were designed at a time when standardization was seen as a necessity and problem-based inquiry teaching methodologies were not valued.

However, Darling-Hammond (2010) suggested that current educational reforms such as NGSS and CCSS/CCRS, seek to encourage schools that will:

> …teach disciplinary knowledge in ways that focus on central concepts and help students to learn how to think critically and learn for themselves, so that they can use knowledge in new situations and manage the demands of changing information, technologies, jobs, and social conditions. (p. 4)

Furthermore, Morgan, Moon, and Barroso (2013) stressed the importance of preparing students for careers that may not exist now. By incorporating science and engineering process skills such as identifying problems and constraints, conducting research, ideating, analyzing, building, testing, refining, communicating and reflecting, students will engage in creating projects and practicing the 21st Century skills that are highly coveted by the technologically advanced global workforce. These skills parallel the suggestion from the National Research Council (NRC, 1996) which indicated that inquiry standards for science should include skills such as:

> …making observations; posing questions; examining books and other sources of information to see what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results…identify assumptions, use critical

and logical thinking and consider alternative explanations. (p.23)

and conduct investigations, use appropriate tools and techniques to gather data, think critically and logically about the relationships between evidence and explanations, construct and analyze alternative explanations, and communicate scientific arguments."

Prior to the onset of NGSS and CCSS, Bellipani and Lilly (1999) concluded that the earlier a student gains experience with science inquiry, specifically, hands-on activities, and develops simple science concepts, the "easier it will be for them to later perform more complex studies in science" (p. 46). DeBoer (1991) supported this argument by indicating that thinking in a scientifically disciplined and rational manner can strengthen "intellectual power" by developing inquiry methods that will be transferable not only to scientific content, but non-scientific content as well.

A common conclusion upheld by science education researchers is that student participation in science and engineering fairs (SEF) has the potential to develop a student's mastery of essential science process skills within the classroom and beyond (Bellipani and Lilly, 1999; DeBoer, 1991; Kormaz, 2012; LaBanca, 2008; McComas, 2011; Sahin, 2011). Defining a researchable question, with scientific phenomena behind it, designing research that is inductive or deductive with multiple hypotheses, and explaining or arguing the findings provides a deeper understanding of the nature of science and the science processes (Tillman, 2011). Tillman suggested that too often science curricula focus on factual information in science without emphasizing the phenomena (2011). He also suggested that as teachers strive to incorporate science process skills in their curricula, the more students will understand how to include them in their science fair projects.

Additionally, McComas (2011) suggested that SEF involves a personal investment in a research topic of design which should make student-centered research a valuable learning tool, molding the learning style of a student toward a higher caliber of scientific discovery. To further support the potential of participation in SEF as a tool to improve upon the achievement of students in the scientific processes, research conducted by LaBanca (2008) and Kormaz (2012) indicated that students who participate in SEF obtain a greater depth of knowledge of engineering and science process skills indicated as essential by NGSS. This further emphasizes the relationship between participation in SEF and the potential for deeper use and application of science process skills.

Therefore, the case can be made that participation in science and engineering fairs has the potential to increase a student's retention of the scientific inquiry content, to integrate science process skills and to enhance the depth of knowledge needed to enter the scientific and technologically advanced workforce (DeClue, Johnson, Hendrickson, & Keck, 2000). Additionally, student involvement in authentic scientific research such as the science and engineering fair establishes a deep appreciation for the nature of science (Bellipani & Lily, 1999; Davidson, 2014; McComas, 1998; 2011; 2015).

Purpose of the Study

The purpose of this study was two-fold. First, the research explored the common factors in teaching methodology that promote scientific inquiry in the classroom through the platform of teacher mentors to SEF finalists. Secondly, the research explored the relationship between SEF participation and academic achievement. Establishing connections among these factors can provide strong links between the science processes employed by students in science and engineering fair participation and academic success.

There are many ways to measure links between exemplary practices (McComas, 2005) and academic performance in science education. However, for the purpose of this study a teacher's success at cultivating Intel International Science and Engineering Fair (ISEF) Finalists and Alternates was selected. A *Successful* or Exemplary Science and Engineering Fair Teacher (ESEFT) is defined as a teacher from the state of Mississippi who has had 2 or more ISEF finalists and/or alternates from the regional, state, national or international competition for the years 2006-2015. Therefore, the focus of this study is to understand how teachers implement science fair into their curricula, the corresponding impact on student learning through teaching strategies that promote science inquiry success, and to explore the influence of science and engineering fairs on student achievement as measured through standardized tests.

The study has the following objectives:

- Determine common factors that contribute to an exemplary science and engineering fair teacher's actions to produce ISEF Finalists and/or Alternates.
- Identify how teachers incorporate science fair into their curricula.
- Link a school's pre- and post- science fair participation level to science inquiry scores on the fifth and eighth grade MST2 standardized test scores.

Significance of the Study

With the emergence of NGSS science and engineering concepts, as well as science practices, educators seek to engage students in higher level learning. Schools are looking for ways to modify or incorporate the higher level learning through STEM education and enhance science programs that will engage students in the implementation

of the new science education initiatives (Sahin, 2013; Tomas, Hackson, & Carlisle, 2014). Science and engineering fair projects are a natural end result of the incorporation of all the aspects of the science and engineering practices found in NGSS (McComas, 2011). Additionally, science and engineering fair projects essentially address the Common Core reading, writing and mathematical practices related to science.

While the literature on science and engineering fair contains (1) anecdotal guidelines for growing a science fair (Anderson, Barnhardt, and Took, 2014; McComas, 2011; Weber, 2015), (2) recommendations for development of science fair projects (Bellipani and Lily, 1999; Callison, 2014; Dionne et al., 2012; Kormaz, 2012; McComas, 2011), and (3) ideas for fundraising and support associated with science fairs (Bunkerson & Anderson, 1996; Grote, 1995; McComas, 2011; Silverman, 2013; Tortop, 2013), there is little research that explores connections to successful teaching strategies that promote the inclusion of science and engineering fair projects in the science curricula. This gap in the literature provides an opportunity for this study to explore the teaching strategies or other common factors of teachers who successfully incorporate science inquiry in their classroom through the alignment of science and engineering fair projects with current science curricula. A case study (Creswell, 2013) analysis of teachers who purposefully and successfully include science and engineering fair projects as the key product of alignment between science practices and curricular standards could provide guidance and guidelines for incorporation of science and engineering fair projects into current science curricula. Lessons learned from this study could inform targeted professional development to guide effective instruction of science process skills and the use of SEF as a deeper learning tool. This could lead to an increase in academic achievement, number

of students participating in science and engineering fairs, and potentially, the number of students seeking STEM careers (Sahin, 2013; Weber, 2015).

It is the intention of this research to create a guideline of "exemplary practices" of science inquiry teaching practices for teachers who have expressed apprehension in participation or inclusion of science inquiry-based projects, science and engineering fair programs, or other associated issues. In particular, the guideline will provide support for evidence of potentially significant academic benefits for inclusion of science and engineering projects in the science curricula. Additionally, establishment of a link between increased science inquiry test scores and the onset of SEF participation could help drive educational policy change in science education. The policy changes in science education could include incorporation of independent student authentic scientific research, such as the science and engineering fair projects, as an adequate in depth assessment of inquiry learning for graduation requirements.

In an effort to provide evidence of successful teaching strategies related to science and engineering fair and academic growth in science inquiry, this study will attempt to research questions pertaining to this relationship.

The overarching questions of this study include:

1. Is there a relationship in the way an ESEFT values the relationship of science inquiry, science process skills and SEF? More specifically, the research explored the following questions:
    - Why do ESEFTs value science inquiry, science process skills?
    - Why do they value and implement science and engineering fair?

2. How do exemplary science and engineering fair teachers integrate science and engineering fair into the science curricula? More specifically, this focal area explored the following questions:
    - How do ESEFTs (exemplary science and engineering fair teachers) prepare students to participate in SEF?
    - In what ways do ESEFTs include science process skills in the instruction they plan to prepare students to participate in science fair?
    - In what ways do ESEFTs include elements of science inquiry-based instruction in the instruction they plan to prepare students to participate in science fair?
    - In what ways do ESEFTs incorporate science and engineering fair into their regular classroom curricula beyond the period of instruction planned to prepare students to participate in science fair?
    - What resources do ESEFTs perceive to support their success with SEF?
3. Does a statistical relationship exist between the onset implementation of science and engineering fair (SEF) participation and science scores on the MST2 for fifth grade and eighth grade?

Overview of Methodology

This study examined science and engineering fair participation in schools across the state of Mississippi. This included an analysis of *successful* or ESEFT who were teachers of ISEF Finalists, and a quantitative analysis linking school participation to standardized test scores in the state of Mississippi on the fifth and eighth grade MST2. In

the qualitative analysis, successful teachers or ESEFTs characterized by the production of ISEF finalists or alternates within the past 10 years were chosen for participation in the study. As indicated by researchers, teachers who have students who win at the state and international level of science and engineering fair value use extensive inquiry strategies within their classrooms that promote deeper learning (LaBanca, 2008; McComas, 2011; Weber, 2015). Therefore, the use of teachers with extensive experience mentoring ISEF Finalists will provide the opportunity to explore common teaching strategies that support the alignment of science and engineering fair projects with the science inquiry portion of the state science curricula. The researcher contacted all of the teachers within the state of Mississippi who fit the criteria and obtained consent to participate in this study. Ten of the twenty identified to fit the criteria according to the highest number of ISEF Finalist and/or Alternates were contacted with six consenting to participate.

The research focused on teaching methodologies and other significant factors that support the alignment of science and engineering fair projects with state science curricula. The researcher conducted face-to-face interviews, observations and collect documents to support the data collection in this study. Questions related to each focus area are listed in the initial interview protocol in appendix C. The researcher used the questions to guide the initial interview. Commonalities in teaching strategies, practice, support, and curriculum alignment that could help to serve others who are implementing science and engineering fair projects as a part of the science curricula to support science inquiry and STEM initiatives were gathered. Upon analysis of the initial interviews, follow-up interviews, observations and documents were collected to support the themes found within the initial data analysis. Observations were not limited to tangible items, but

also included school/classroom climate, socio-economic and other demographic information. As part of the data collection process, participant teacher's scores were be collected from the state level website.

In the quantitative analysis, the data obtained from Mississippi Department of Education (MDE), the seven Regional Fairs in Mississippi, and National Strategic Planning & Analysis Research Center (nSPARC) were be analyzed for relationships between the onset of school level science fair participation and scores on the fifth and eighth grade. Dates indicating the onset of a change in support of science fair participation will be obtained from the State of Mississippi Science and Engineering fair databases. Standardized test scores were calculated from student level data obtained from Mississippi LifeTracks system were compared to pre- and post- science and engineering fair implementation to assess the impact of SEF as an instructional practice.

Assumptions and Limitations of the Study

The teachers that have been identified for the qualitative study were diverse; they varied in ethnicity, school size, socio-economic background, gender, age, teaching experience, and education level, so this was a potential threat to internal validity. There were occasional similarities in demographics, however most demographics vary widely (see appendix A). The differing school environments could potentially influence the results due to the diversity of the schools. The population to be studied will be *successful* secondary school teachers or ESEFTs that showed excellence in producing Intel ISEF finalists and alternates over a ten year period or exemplary science and engineering fair teachers. Exemplary science and engineering fair teachers in this case were defined as those teachers who had 2 or more ISEF finalists or alternates within the past 10 years.

Twenty teachers fit the criteria and six were studied. There was a risk successful teachers could have been excluded by focusing on only a 10-year period. It is the assumption of this researcher that this study has limited generalizability with participants who agreed to participate, answer honestly, and seek no notoriety for participation.

Additionally, the state standardized assessments items for science inquiry were included in the MST2 for fifth and eighth grade. However, the teacher guides (2011-2012) indicate that only 9 of 55 items assess inquiry on the fifth grade MST2, and 15 of 60 items on the eighth grade MST2 (see Appendix D). While the validity of the measure of science inquiry on the MST2 is in with the alignment of the competencies and objectives in the 2010 Mississippi Science Framework and the academic performance level descriptors, it is consistently measured the same for all students across the state of Mississippi. Therefore, the MST2 for fifth and eighth grade provided ample comparison for statistical validation of science academic achievement. Although the archived data used in analysis were collected at the student level, composite scores and researchers could not dial down to individual inquiry sub scores. Because only a few of the items directly assess students understanding of science process skills this limits our ability make it a direct correlation between student achievement on inquiry items and science fair participation. Often science fair participation is promoted through promises of increased standardized test scores. It is the goal of this study to validate that claim.

CHAPTER II

REVIEW OF LITERATURE

This chapter discusses the literature related to science process skills, science inquiry and the nature of science. This is followed by research related to science fair, including efficacy, economic impact, and aptitude or ability to do inquiry. Lastly, the gaps in the research are identified with supporting evidence for the importance of this study.

Science Process Skills

A common goal of education is to teach students how to think. To accomplish this overall goal in science education, the Science-A Process Approach (SAPA) indicated that the process of learning science focuses on learning how to use and apply scientific thinking and skills (Padilla, 1990). These skills are broad, transferable and reflective of the behavior of scientists. In general, process skills refer to the cognitive or thinking processes in which the learner is engaged while learning a subject. While participating in process skills, the learner is producing a product. Therefore, the products of learning are generated through the use of process skills. Those process skills which are more often emphasized by learners of science and scientists and are productive in better learning and problem solving are called process skills in science.

Sheeba (2013) defined science process skills as the "building blocks of critical thinking and inquiry in science that can be gained through precise science education

activities" (p. 108). The science process skills reflect intellectual skills, associated psychomotor and affective skills that are concerned with the learning of science in all its aspects. Science process skills of the cognitive domain are: comparing, communicating, inferring, predicting, using number relations, using time/space relations/making operational definitions, forming hypotheses, controlling variables, interpreting data, generalizing, raising questions, applying quantifying, evaluating, designing, investigating, finding relationships and patterns (Padilla, 1990). The psychomotor domain of the science process skills includes observing, classifying, manipulating, experimenting and measuring (Sheeba, 2013).

Science process skills can be successfully developed by engaging learners in authentic learning activities (Keys & Bryan, 2001). Teachers who focus on inquiry-based instruction in the science classroom, provide opportunities for students to use and adapt science process skills. Feyzyodlu (2009) indicated a direct relationship between the affective use of science process skills in laboratory investigations and increased science achievement in Chemistry education. Additionally, students who were exposed to authentic learning activities in an inquiry-based middle school classroom had a significant increase in science performance (Felita, 2008). Science education activities such as science and engineering fair projects provide opportunities for students to master and apply the most basic science process skills while integrating higher level science process skills (McComas, 2011). Therefore, the research suggests that teachers who provide opportunities for hands-on deeper learning investigations involving science process skills have a propensity for increased student science achievement.

Science Inquiry

Teaching strategies that involve the use of inquiry are commonplace in the science classroom. The nature of science inquiry is such that the less that is given to the learner, the higher the level of inquiry (Herron, 1971). There are four levels of inquiry: confirmation/verification, structured, guided, and open (Tafoya, et.al., 1980). Olhoff (2006) describes the four levels of inquiry as an incremental voyage into deeper learning. As the learner progresses from confirmation to open inquiry, the learner is in increased control of the learning process, while the teacher becomes more of a facilitator. As teacher involvement decreases, student direction and engagement increases. Student discovery or engagement increases, critical thinking and problem solving become second nature (Shope & McComas, 2015). As a student's engagement in science inquiry increases, the use and integration of science process skills creates experiences where the students are gaining confidence and a deeper understanding of their content (Tillman, 2013). As students invest in the learning experience, academic achievement increases. Thus, open inquiry experiences, such as SEF, provide students with the opportunity to engage in higher order inquiry critical thinking.

The Nature of Science

Lederman (1998) identified the consensus definition of the nature of science (NOS) as "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (p. 833). Furthermore, Lederman indicated the understanding that the NOS includes science process skills and science inquiry. Although he suggested that scientific processes are actual activities that use scientific inquiry in a "cyclical manner" (p. 835), he further distinguished that NOS is

much more than science inquiry and science processes. Specifically, Lederman (2006) highlighted seven crucial distinctions for determining the understanding of NOS. They include: (1) The distinction between observation and inference; (2) The distinction between scientific laws and theories; (3) The involvement of human imagination and creativity; (4) Scientific knowledge is subjective; (5) Science is a product of culture; (6) Science is never absolute or certain; (7) Important to distinguish between NOS and science inquiry or science processes (Lederman, 2006, pp. 833-835).

The all-encompassing theme of NOS is also reflected in McComas's (1998) description of NOS, where he describes NOS as a:

> "blend of various social studies of science including history, sociology, and philosophy of science combined with research from the cognitive sciences…into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors" (p. 4).

Both descriptions of NOS by Lederman and McComas speak to the importance of science processes and science inquiry as a either a portion of NOS or the incorporation of both throughout. Perhaps if NOS and specifically, science process and science inquiry are explored through the platform of SEF, teachers and students could achieve a greater understanding of the whole of NOS.

History of Science Fair

In 1828, the American Institute of Science and Technology (AIST) held the first Science and Technology exhibition (Dutton, 2011; Silverman, 1986). In 1928, AIST in cooperation with the American Museum of Natural History held the first student science

fair (Bellipani & Lilly, 1999; McComas, 2010) which set a precedence for all future science fairs (Bellipani & Lilly, 1999). This eventually evolved into the ISEF of today. However, there is not one sole contributor to the formation of the current ISEF. Many organizations, clubs, competitions and similar events have been instrumental in the development of student-centered research (Bellipanni & Lilly, 1999; Dutton, 2011).

In 1921, The Science Service of Washington, D.C., a nonprofit organization established to discredit pseudoscience, was charged with generating public interest in the sciences. They outlined a mission to promote science through education. The Science Service Publication has now evolved into the weekly periodical, *Science News.* Science Service and the American Institute of New York City established the Science Clubs of America in 1941. In the early 1940's Science Service and American Institute of Science joined forces to create a non-profit group, Society for Science and the Public. Science Service, co-founded in 1921 by Edward Scripps and William Ritter, also partnered with G. Edward Ferdrey of Westinghouse to sponsor the Science Talent Search (STS) in 1942. The STS, which is now sponsored by Intel and the Society for Science and the Public (SSP), contributed to the development of the first National Science Fair in 1950 (Dutton, 2011) in Philadelphia, PA. The non-profit group SSP, initial fair has grown from 30 finalists in 1950 to over 300 in 1960 to now almost 1800 in 2015 (Intel ISEF, 2015). The rise in growing interest of the science fair was sparked by events in the late 1950's.

In the Post-Sputnik era of the 1950's, science clubs and fairs continued to increase in number. The 1957 the Russian launch of Sputnik generated a concern that the United States was falling behind in math and science education (Gibbs & Fox, 1999). This heightened concern of the competitive factor and the success of the National Science

Fair, led to the creation of the first International Science and Engineering Fair in 1964 in Baltimore, Maryland (Brown et al., 1986; Intel ISEF, 2015; and LaBanca, 2008). The International Science and Engineering Fair is currently supported largely by the Intel Corporation and Society for Science and the Public. The Intel ISEF attracts students from over 70 countries to compete for scholarships, awards, and prizes valued at over $4 million (ISEF, 2015). While students have been participating in science and engineering fairs for almost one hundred years, there is little research on the relationship of teaching strategies and the academic benefits of participation in science and engineering fair processes.

Efficacy of Teacher

A search of the literature involving science and engineering fairs indicated a focus on efficacy for a large portion of the research. In particular, research involving the efficacy of teachers (Dionne et al., 2012; McComas, 2011; Shirver &Czerniak, 1999) and students (Blenis, 200; Callison, 2014; Czerniak & Lump, 1996; Finnerly, 2013; Miles, 2012; Sahin, 2013) in relationship to science and engineering participation indicated mixed emotions related to environmental perception and academic inclusion of the science and engineering fair process. Additionally, the topics of mandatory participation versus competitiveness, economic development (Vencia, 2006; Voncovik & Potocnik, 2010; Weber, 2015) and matriculation in to science or STEM career paths (Sahin, 2013) as a common theme are often related to self-efficacy of science and engineering fair programs,. Very little research has been conducted on a relationship between science and engineering fair participation and increased academic performance. LaBanca (2008) suggested that science fair participation increased the student's inquiry or "problem

finding" aptitudes. However, the sample population only included State of Connecticut SEF winners and 12 Intel ISEF Finalists.

Research indicates teachers generally feel the experiences of science and engineering fair projects are beneficial to the student (Bunderson & Anderson, 1996; Grote, 1995; Rillero & Zambo, 2011). When considering teacher efficacy for SEF, Shriver & Czerniak (1999) suggest that a teacher's efficacy for SEF varies and no factor that can determine efficacy for science fair. In a study of pre-service teachers, the response to SEF was overwhelmingly positive with many citing evidence of the benefits of student participation in science and engineering fair projects (Bunderson & Anderson, 1996; Grote, 1995). However, with experienced teachers, patterns were evident that adequate administrative support, years of teaching experience and years of SEF participation were key factors in a teacher's efficacy for science fair. McComas (2011) suggested that there must be a successful link between professional development and teaching strategies for successfully integrating science fair into science curricula. Administrators and teachers must consider the balance of demands on curricula with time it takes to support the projects. McComas suggests that these issues could be addressed with afterschool programs, embedding science fair into research courses, embedding science fair into science curricula, treating science fair participation like a sport, and compensating teachers for additional work. McComas also suggests that schools with longitudinal perspectives for incorporation of science fair into curriculum achieve success. Additionally, most teachers' opinions of science fair are strong (Rillero, 2011). They base their efficacy of science fair on personal experiences and preferences, not research. According to Dionne et al. (2012) understanding research-based anticipated

benefits of student participation in science and engineering fairs could potentially assist science teachers in adapting instruction to appeal to a wider range of students in schools, "thus nourishing the emergence of more interest in science" (p. 669).

Efficacy of Student

Supporters of science fair indicate that one of the benefits of science and engineering fair projects is the opportunity for students to engage in an inquiry experience (Bellipani & Lilly, 1999; Dionne et al., 2011; Rillero & Zambo, 2011; Sahin, 2013; Sayer & Shore, 2001; Sumrall & Schillinger, 2004). Research indicates that students who participate in inquiry based learning have increased motivation towards science (Bahar, 2009; Ndlovu, 2013; Tomas, Jackson, & Carlisle, 2014; Tuan, Chin, Tsai and Cheng, 2005).

A review of a study on student efficacy of SEF indicated that fifth grade students who participated in SEF, regardless of mandatory participation or competitiveness, exhibited positive attitudes and increased interests toward science (Blenis, 2000). However, low-achieving students with mandated participation showed greater improvement in science efficacy than high achieving students with mandated participation in science fair. Additionally, regardless of the mandating of science and engineering fair participation, all showed an increase in science efficacy in a non-competitive environment. In studies similar to Blenis (2000) efficacy of science through science fair participation, Czerniak & Lumpe (1996) indicated an increase in science efficacy through non-competitive collaborative learning. This research supports the National Science Teacher Association (NSTA) position on science fair, which states that science fair participation should be voluntary.

More recent studies related to science efficacy (Finnerly, 2013; Miles, 2012; Sahin, 2013), indicates student's efficacy towards science, SEF, and science or STEM careers increase with participation in SEF. A South African study including over 300 seventh through twelfth grade students compared the level of amount of inquiry in the classroom versus science fair participation. Researchers found overwhelmingly that students believed the science fair projects were more inquiry based than their classroom experiences (Ndlovu, 2013) and provided them the opportunity to be independent learners vested in a topic of their own interests. A similar study indicated that student motivational factors for completing a science and engineering project include: "interest in science content; sense of self-efficacy; assurance of achievement through rewards or gratifications; social aspect of participating; and working strategies to gain scientific knowledge and methods" (Dionne et al., 2011, p.1). Although increases in science efficacy are beneficial to a student's achievement in science, it is not an adequate measure of academic aptitude or depth of knowledge gained from participation in SEF.

Sam Marshall, as cited by Callison (2014), indicates that efficacy of science begins when students can envision science exploration in their own backyard. This is evident in a study promoting efficacy of science through science fair participation, where students were encouraged to incorporate the ocean science fair model to include criteria for cultural and/or community relevance (Dublin, Sigman, Anderson, Branhardt, & Topkik, 2014). The researchers' engagement of Alaska Native and rural students in "science practices relevant to their cultures and communities" through the science fair program resulted in positive learning outcomes. Additionally, the students projected strong positive feelings of science efficacy, investment in the nature of science, and

connections with student scientists supporting and vesting in the future development of their communities.

Modern Expectancy-Value Theory

The *Modern Expectancy-Value Theory* originally defined by Atkinson (1964) is an expectancy-value model that highlights an individual's affirmation of task-specific beliefs with attainment and value (Eccles et al., 1983). Additionally, attributes of the model, such as intrinsic value, utility value, extrinsic values or reasons for engagement, and academic performance prediction (Feather, 1988; 1992) have the potential to influence cognitive and motivational constructs. Teaching strategies that promote the use of inquiry through promoting successful science inquiry through design, analysis and presentation, such as those utilized in a science and engineering project will empower students to become self-motivated, develop efficacy for science inquiry, find the usefulness or real world application for inquiry, engage in the need for achievement or reward for academic accomplishment culminating in the science and engineering fair project design process.

Value, as defined by Higgins (2007) is the relative worth of a commodity, activity or person. In this study, the concept of value leads to several questions. What is the value of conducting a science fair project? How does this attract or repulse motivation? What are the beliefs that surround the development and attainment of academic achievement through the participation in the science fair project? Does the value of mastery of the inquiry type tasks relate to the expectancy of academic achievement through participation in the science fair project? Tillman (2011) suggests that teachers who see the value in incorporation of science inquiry activities, such as science and engineering fair projects,

produce students with a greater understanding of how to "do" science. The students become vested in the content, internalizes the value, and this grows the relationship between intrinsic and utility value of the related tasks for potential future career choices (DeClue, Johnson, Hendrickson, & Keck, 2000).

Expectancy, as defined by Eccles and Wigfield (2002), is the belief in obtaining a goal. Although this may seem similar to Bandura's theory of self-efficacy, Bandura indicates that expectancy and self-efficacy are related, but distinctly different. Further distinction by Williams (2010) clearly distinguishes outcome expectancy from self-efficacy, indicating that "self-efficacy is perceived ability to do a behavior, whereas outcome expectancies are judgments about the likelihood of outcomes that flow from behavior" (p. 418). Pekrun (2009) also defines expectancy as belief in obtaining a goal, but intuitively explores linkages to consequences of actions and control of outcomes. Therefore, the approval or use of tasks, activities or actions gives value to the outcome. If the individual is ultimately expecting to obtain a certain outcome and believes that certain activities or actions will produce that outcome, research suggests they will see value in the activities and increase motivation to achieve academic success (Pekrun, 2009). If a teacher expects that certain tasks will increase science process skills; and mastery of those skills will result in success, the teacher expects the student to achieve academic success.

In the Modern Expectancy-Value Model, extrinsic value includes other aspects that might influence the perception of the value of, in this case, science fair and science inquiry. For example, money or scholarships, notoriety, patents, or other items have extrinsic value, and these often lead to pleasure which can be perceived as intrinsic value.

Intrinsic value correlates more with the personal value in an object, concept or activity. This can include judgments, responsibilities, and enjoyment (Eccles & Wigfield, 2002). McComas (2011) identifies development of intrinsic value as the most important factor in understanding the concept of inquiry through the nature of science. Lederman (1999) explains that a student's grasp of the nature of science, e.g. its realm and limits, levels of uncertainty, consequential biases, social aspects, and the reasons for reliability are strongly influenced by the intrinsic value of the nature of science by the teacher. Lederman's research indicated that a teacher who pays explicit attention to the relationship of the nature of science in the planning of lessons, activities or other instructional material will inadvertently promote the intrinsic value of the nature of science and science inquiry. If students internalize the interaction of the nature of science, or what a scientist really does, and practices science inquiry through authentic research such as science fair, a deeper understanding of the relevancy of science and science inquiry is achieved.

Additionally, intrinsic value can often lead to utility value. As described by Eccles and Wigfield (2002), utility value is "determined by how well a task relates to current and future goals, such as career goals" (p. 120). If intrinsic value is established, it is much easier for an individual to make the connection between internal (intrinsic) value and future career goals. In the context of this research, teachers who value science inquiry and science and engineering fairs, and promote that same intrinsic value to their students, provide an expected pathway to future careers. As indicated by researchers (McComas, 2011; Sahin, 2013; Tillman, 2011; Weber, 2015), a greater percent of future career

choices in the STEM fields are directly related to the experiences and value placed on science inquiry and science fairs in secondary education.

Academic performance prediction as described by Eccles et al. (1983) is the belief that completing certain tasks will result in higher academic achievement. Eccles indicates that this can be influenced by school evaluations, competition, and social comparisons. No research could be found that connected value of science inquiry and science fair to predicting academic performance. However, in a study on low-achieving versus high-achieving students, Czerniak & Lumpe (2009) indicated that competition was a large factor in deterring those students who were low-achieving. Competition was also perceived by teachers and researchers to have less intrinsic value for science inquiry and science fair. Consequently, the high-achieving students indicated a greater intrinsic value for science inquiry and science fair with a favorable outlook on competitions. Therefore, competition deterred low-achieving students and excited high-achieving students.

Motivational and cognitive constructs are closely intertwined. Motivational constructs, e.g. motivational goals of mastery and performance, individual and situational interest, and extrinsic/intrinsic factors, are defined as those beliefs that fuel our desire to achieve, participate, and be successful (Park, 2011). Cognitive constructs, such as critical thinking and creativity, can be defined by the rational cognitive processes leading to motivation and behavior. This can also lead to self-regulated students that are achieving their own learning goals (Zimmerman, 2000). Therefore, what motivates a student to have intrinsic value for science inquiry and science fair? How does the value of science inquiry and science fair by the teacher relate to the expected outcomes of the student? Some research suggests that teachers play a large role in guiding students to value science

and science inquiry (Singh, Granville, & Dika, 2002). By providing opportunities for engaging activities and promoting the value of those activities, teachers stimulate students' interest in science and science inquiry. It is evident that teachers are a key player in the motivation of students for science and its intrinsic value in their lives.

Economic Impact

In addition to expectancy and value of science efficacy, science and engineering fairs and academic aptitude, a search of literature linked participation in science and engineering fairs to economic development. Vincovik and Potocnik (2010) attempted to address the decline in youth interest in science and technology in Croatia. Efficacy for science was directly correlated to teaching methods that promoted rote memorization with little activity, rare presentation of work, with little opportunity for analysis or investigation. Croatia's decline in economic development was at a critical precipice sparked by a lack of people to fill science and technological positions. In an effort to increase efficacy for science and "increase human capital" for science and technology jobs, the researchers utilized the commonality of participation in science and engineering fairs in Croatia, although admittedly not the best methods, to universally increase science and technology in the classroom. Rural areas or less economically developed areas had significantly lower performances on science fair. The researchers suggest that this could be related to the inability to attract high quality teachers. However, in areas where high quality teachers existed with socioeconomic stimulus, science fairs seemed to correlate with good economic development. This research failed to relate science scores with improvement academically. Additionally, this research did not track the growth of students who participated in science fair as a whole.

In a similar study in Costa Rica, the 2004 national mandate of science and engineering fairs with full implementation in all science curricula was initiated with institutional participation and further competition by choice from pre-school through twelfth grade. Valencia, as cited by Weber (2015), reflected that participation in science and engineering fairs has promoted a science and technology culture in Costa Rica. Weber's research showed that teachers and administrators feel that STEM or science and technology fair participation is essential to the economic future (of Costa Rica). Like Croatia (Vincovik & Potocnik, 2010), a strong momentum to integrate science fairs into science curricula and mandate science fair participation seemed to increase student efficacy for science and technology and provide a positive impact on the students' lives. Costa Rican school administrators, teachers and students aligned positively the theme for support for integration in STEM education to grow Costa Rica's human capital and economy.

In the United States, many rural areas struggle with funding for education, fueled by downtrends in economic climate. Additionally, many current jobs in the STEM fields are outsourced to, or individuals are recruited from, other countries. Companies site the lack of individuals with STEM credentials as the number one reason for outsourcing jobs (NRC, 2011). Just as the onset of the Sputnik era sparked the introduction of science and engineering fairs in all schools with the hopes of producing future scientists, the support of science and engineering fair in schools once again, could potentially increase the number of individuals in the United States who are highly qualified for STEM careers (Adelman, 2006; Cleaves, 2005; Munro & Elsom, 2000; Sahin, 2013). The increase in employable STEM individuals in the United States has the potential to fuel the economy

in an upward directions. Support for teaching strategies that incorporate science and engineering fair into the curriculum could foster interest towards STEM careers, thus increasing the number of employable STEM majors in the United States (Sahin, 2011).

Academic Aptitude and Ability to Do Inquiry

Bellipani & Lilly (1999) agree that the science and engineering fair project is a form of independent research that acts as an authentic assessment or practice of the student's scientific process skills. Science education research is in consensus that students who participate in SEF and other STEM programs should obtain a deeper breadth of knowledge of science inquiry (Finnerly, 2013; LaBanca, 2008; McComas, 2011; Sahin, 2013). Many researchers have indicated that students who participate in science and engineering fairs are more likely to choose career paths in the STEM fields (Sahin, 2014; Woolnough et al., 1997). LaBanca suggested that science fair participation increased students' inquiry or "problem finding" aptitudes. However, the sample population only included State of Connecticut SEF winners and 12 Intel International Science and Engineering Fair (Intel ISEF) winners. In a study related to science discourse, students were found to increase their authentic 'science talk' while explaining their science fair projects (Gomez, 2007). This aligns with the NAEP 2011 Science Framework, which stresses the importance of scientific literacy through accurate and effective communication (NAEP, 2010) as well as the previous scientific literacy goals outlined by the American Association for the Advancement of Science in Project 2061 (1989). In addition, the NGSS practice of engaging in argumentation from evidence supports the push for scientific literacy (NGSS, 2015). However, once again, little

research has been conducted that specifically addresses the effect of science fair participation on science inquiry aptitude.

Is there a way to measure the effect of science fair participation on science inquiry aptitude? In the state of Mississippi, students are tested for science aptitude in a standardized format three times in grades K-12. The Mississippi Science Test (MST2) is administered at the same time and day of the year to all students in public schools in the fifth and eighth grade. Additionally, the Mississippi Subject Area Test (SATP2) for Biology occurs generally in the ninth or tneth grade. A portion of each test includes inquiry based questions aligned with the inquiry strand in the Mississippi Science Curriculum (MDE, 2010). The teacher guides (2011-2012) indicate that only 9 of 55 items assessed inquiry on the fifth grade MST2, 15 of 60 items assessed inquiry on the eighth grade MST2, and 7 of 60 items assessed science inquiry on the Biology SATP2 (see Appendix D). However, the standardized assessments are limited in their ability to adequately assess inquiry due to the use of multiple-choice response questions. As indicated by Resnick and Resnick, (1992), science inquiry involves higher-order thinking skills that cannot be adequately measured by multiple-choice response questions. However, for the purposes of this study, the statewide standardized MST2 and Biology SATP2 assessments will be assumed to have a reasonable measure of educational output that can be used to provide science inquiry scores for all schools in the state of Mississippi. Sample items for the inquiry construct are included in Appendix E.

Focus of Research

In an effort to provide evidence of successful teaching strategies related to science and engineering fair and academic growth in science inquiry, this study explored the following questions pertaining to this relationship:

1. Is there a relationship in the way an ESEFT values the relationship of science inquiry, science process skills and SEF? More specifically, the research explored the following questions:
    - Why do ESEFTs value science inquiry, science process skills?
    - Why do they value and implement science and engineering fair?
2. How do exemplary science and engineering fair teachers integrate science and engineering fair into the science curricula? More specifically, this focal area explored the following questions:
    - How do ESEFTs (exemplary science and engineering fair teachers) prepare students to participate in SEF?
    - In what ways do ESEFTs include science process skills in the instruction they plan to prepare students to participate in science fair?
    - In what ways do ESEFTs include elements of science inquiry-based instruction in the instruction they plan to prepare students to participate in science fair?
    - In what ways do ESEFTs incorporate science and engineering fair into their regular classroom curricula beyond the period of instruction planned to prepare students to participate in science fair?
    - What resources do ESEFTs perceive to support their success with SEF?

3. Does a statistical relationship exist between the onset implementation of science and engineering fair (SEF) participation and science scores on the MST2 for fifth grade and eighth grade?

In theory teachers who have had success at the international level in the International Science and Engineering Fair or ESEFTs, possess a unique set of teaching strategies or best practices that promote continual success. The strategies are fueled by the perception of the value of science and engineering fair as an effective and essential portion of the science curricula. Additionally, participation in science and engineering fair (McComas, 2011) promotes a deep understanding of the nature of science (Lederman, 1999) including science processes and science inquiry skills highlighted in all science curricula. However, current statewide science curricula assessments that are multiple choice assessments may not adequately assess inquiry (Ketelhut & Dede, 2014). Current teaching strategies used in the classroom seem to align with a push to cover content for a standardized test, instead of valid inferences about whether a student has learned to engage in inquiry (McComas, 2015). Therefore, the use of science and engineering fair projects as authentic student scientific research as a means of assessing students' understanding of inquiry process could be a valid measure of the students' inquiry skills (Ketelhut & Dede, 2014). Theoretically, the best practices of successful teachers with the incorporation of authentic student research (ISEF or SEF) should increase the ability of students to do inquiry and provide a critical thinking foundation that will make them more competitive in the global workforce.

As educational reforms seek to invest in the value of science inquiry in science curricula, teachers will search for ways to incorporate science inquiry through strategic plans or projects that provide opportunities for students to engage in independent inquiry-based learning, such as the science and engineering fair project. With science educational reforms and STEM initiatives promoting the inclusion of science inquiry, it is ironic that the number of schools participating in science and engineering fair is on the decline (Harmon, 2010). Perhaps if teaching methodologies that support the alignment of SEF with applicable knowledge of science inquiry within the state curricula are outlined, educators, teachers, and legislators will once again see the benefits science and engineering fair projects instill in students.

CHAPTER III

RESEARCH METHODOLOGY

This chapter contains the research questions and a detailed discussion of the methods used to answer those questions. The procedures for data analysis is also included for both the qualitative and quantitative portion of the study. Upon selection of exemplary science fair teachers, this study used interviews, observations, and documents to identify best practices or other common factors among successful science fair teachers. In this study all of the interviews were conducted solely by the researcher. The interviews were based on the semi-scripted interview guide in Appendix C. The observations and documents were used to further evaluate and validate relationships from the interviews. Additionally, the methodology for obtaining and analyzing school test scores per science fair participation is outlined.

Qualitative Research

Qualitative Research Questions

There are two main focal areas of the qualitative portion of this research. The first portion of the qualitative research explored the extrinsic and intrinsic values in relations to science inquiry and SEF. The second focal area explored how exemplary science and engineering fair teachers integrate science and engineering fair into the science curricula. More specifically the qualitative research questions were:

1. Is there a relationship in the way an ESEFT values the relationship of science inquiry, science process skills and SEF? More specifically, the research explored the following questions:

    - Why do ESEFTs value science inquiry, science process skills?
    - Why do they value and implement science and engineering fair?

2. How do exemplary science and engineering fair teachers integrate science and engineering fair into the science curricula? More specifically, this focal area explored the following questions:

    - How do ESEFTs (exemplary science and engineering fair teachers) prepare students to participate in SEF?
    - In what ways do ESEFTs include science process skills in the instruction they plan to prepare students to participate in science fair?
    - In what ways do ESEFTs include elements of science inquiry-based instruction in the instruction they plan to prepare students to participate in science fair?
    - In what ways do ESEFTs incorporate science and engineering fair into their regular classroom curricula beyond the period of instruction planned to prepare students to participate in science fair?
    - What resources do ESEFTs perceive to support their success with SEF?

Qualitative methods introduction

The qualitative portion of the study included participants who have been identified as EFEST in the state of Mississippi. The criteria used to identify an EFEST

included teachers who have successfully mentored ISEF Finalists or ISEF Alternates through the regional, state and international SEF competitions more than 3 times in the last 10 years. Individual teacher's consent for participation in the study was obtained (Appendix B). Each ESEFT participant was assigned a code or pseudonym for identification purposes and to maintain confidentiality. A total of 20 individuals in the state of Mississippi were identified to fulfill the criteria for an ESEFT, having had two or more ISEF finalists or alternates within the past 10 years. The ESEFTs were contacted through a scripted email or phone call (Appendix C) for the initial interview and time.

Overview of Qualitative Data Collection

Data collection in this study consisted of several phases: (1) a 45-75 minute audio-recorded interview, (2) biweekly email journals with follow-up emails for clarification as needed, (3) one classroom observation per participant, (4) one summative interview per participant, (5) and follow-up interviews for clarification as needed. The duration of this study was approximately two months. Before the initial interview occurred, participants were asked to complete a demographic sheet and the information was compiled (Table 1).

Table 1

Demographics of Exemplary Science and Engineering Fair Teacher Participants

Participant	Race	Gender	Age	Year of Experience	Years of Science Fair	School Type	Grade Level
Ms. Jude	White	Female	41	20	12	Rural	eighth-9th
Ms. Leslit	Black	Female	52	31	16	Urban	9th
Ms. Tyran	Black	Female	62	40	32	Rural	2nd-12th
Ms. Clane	Black	Female	65	38	33	Rural	9th-12th
Mr. Anders	White	Male	38	8	5	Urban	9th-12th
Ms. Mahon	Black	Female	58	33	28	Urban	9th-12th

The initial interview consisted of questions related to the topics of preparing students for participation in SEF, teaching strategies involved in the inquiry process or science inquiry, the incorporation or alignment of SEF to current science curricula, planning for instruction and support beyond the classroom for SEF, and support systems for SEF .

Throughout each of the phases of data collection, participants were asked to provide documents to support their responses. Documents collected consisted of instructional artifacts related to science and science fair instruction, and included, but was not limited to, lesson plans, worksheets, activity sheets, laboratory sheets, checklists, "how to" lists, pictures of classrooms, etc. Documents included de-identified student samples from previous years used as examples in the current classroom setting. If an ESEFT provided artifacts or documents from previous student work, they were asked to

remove all personally identifiable information from the artifact before submitting the artifact.

Initial Interviews

The initial interview protocol (Appendix D) commenced with stating the purpose of the interview, confidentiality clause, researcher's contact information, and ease of decline of participation statement. Consent of participation forms were obtained at this time as well. The interview questions had directly related to the two qualitative research questions with multiple areas of focus as indicated in Table 2.

Table 2

Relationship of Research Questions to Initial Interview Questions

Research Question 1	**Is there a relationship in the way an ESEFT values the relationship of science inquiry, science process skills and SEF?**	
Focus Questions	**Summary of Modern Expectancy Value Content**	**Interview Questions**
a. Why do ESEFTs value science inquiry and science process skills?	• Extrinsic • Intrinsic • Utility Value • Academic Performance • Motivation • Cognitive	2,3,4,5,6,7,8,16,17
b. Why do ESEFTs value and implement SEF?	• Extrinsic • Intrinsic • Utility value • Academic performance • Motivational constructs • Cognitive constructs	5,9,10,11,12,13,14,15,16,17

Table 2 (Continued)

Research Question 2	**How do exemplary science fair teachers integrate science and engineering fair into the science curricula?**	
Focal Area	**Summary of Question Content**	**Interview Questions**
a. How do ESEFTs (exemplary science fair teachers) prepare students to participate in SEF?	• Define ESEFT • Personal experience with SEF • High Quality SEF project • Activities to promote SEF in the classroom • Identify ingredients of success • Collect supporting documents	1,2,3,4,7,17
b. In what ways do ESEFTs include science process skills in the instruction they plan to prepare students to participate in science fair?	• Identify science process skills used in classroom • Incorporation of science process skill into SEF • Collect supporting documents	8,9,16,17
c. In what ways do ESEFTs include elements of science inquiry-based instruction in the instruction they plan to prepare students to participate in science fair?	• Preparing for inquiry in the classroom • Types and progression of inquiry in the classroom • Relationship between science inquiry and science curricula, standardized assessment • Relationship between science inquiry and assessment • Relationship of inquiry to SEF	8,10,11,12, 13,14,15,16,17

Table 2 (Continued)

d. In what ways do ESEFTs prepare for the inclusion of science and engineering fair into their regular classroom curricula beyond the period of instruction planned to prepare students to participate in science fair?	• Success of inclusion of SEF in classroom • Preparing for SEF and Science Inquiry • Outside instruction for SEF	7,8,14,16,17
e. What resources do ESEFTs perceive to support their success with SEF?	• Support systems (administrative, teacher, student, program, class, community)	6,17

Each focal area was addressed by specific questions outlined in the table above. Overlap among questions was expected, but each interview question was designed to specifically address one focal area of the research question.

Journaling

In an effort to increase the validity and depth of the data collected, the ESEFTs were encouraged to journal while teaching the unit. Journaling was conducted through biweekly email reminders. On the same day of the week, each participant was sent an email with open-ended prompts (example in Appendix F) that focused on the exemplary teaching practices or issues surrounding the use of science process skills, science inquiry and implementation of science and engineering fair projects in the classroom. The questions contained one reflective question and 1 or 2 other questions for clarification. The participants were encouraged to submit supporting documents for the journal submissions or provide artifacts as needed.

Verification of selected population of ESEFTs as ESTs

For the purpose of this study, an ESEFT was defined as a teacher who had successfully mentored 2 or more International Science and Engineering Fair Finalists in the past 10 years. During the interview, each ESEFT was asked to define the difference between an EST and an ESEFT. Mr. Anderson concisely explained that a teacher can be an EST but not an ESEFT. However, an ESEFT, must first be identified as an EST. In an effort to determine if ESEFTs were in fact ESTs, an observational tool was used to identify key characteristics of an exemplary science teacher.

The researcher used an established rubric or science classroom observation guide or SCOG (Appendix H) to collect evidence of classroom culture, intellectual engagement, understanding and connections to scientific content. The North Cascades and Olympic Science Partnership devised the SCOG based on research from *How People Learn* (Bransford, Brown and Cocking, 1999) and *Inside the Classroom: Observation and Analytic Protocol* from Horizon Research, Inc. "The observation tool included four main components:

1. Classroom Culture is Conducive to Learning Science
2. Science Content is Intellectually Engaging
3. Instruction Fosters and Monitors Student Understanding
4. Students Organize, Relate and Apply Their Scientific Knowledge"

In particular, the observational tool or Science Classroom Observation Guide (SCOG) was used an assessment tool of effective science instruction. My original intent was to use the SCOG during each classroom observation and analyze the results of the Likert scale style assessment. On a scale of 1 as not evident and 4 as exemplary, each ESEFT

scored a perfect 4 on every aspect of the SCOG. In an effort to validate these results, a colleague who was unaware of the aspects of this research was asked view the classroom observation videos and use the SCOG to assess each ESEFTs understanding of effective science instruction in classroom practice. The results were identical. For this population of ESEFTs, the data indicated that they exemplify effective science instruction and thus can be considered both ESTs and ESEFTs.

Additionally, during the classroom observations supporting documents were obtained as needed (i.e. lesson plans, classroom documents, pictures, school climate, etc.). The purpose of the observation was to provide support or validation for data collected during the initial interview and journaling submissions. The focus of data collection included occurrence of science process skills, types of science process skills and science inquiry, teaching strategies surrounding implementation of science process skills, and other significant points of interest related to the research question.

Additionally, a tally sheet (Appendix E) with descriptive notes was used to guide the data collection.

Summative Interviews

A summative interview was conducted with each ESEFT participant to clarify any additional questions or insights that arise during the data collection process. The summative interviews included the following questions:

1. What do you think about current SEF projects?

2. What do you think constitutes a strong SEF project? May I see an example of what you consider to be a strong SEF?

2. What do you think constitutes a weak SEF project? May I see an example of what you consider to be a weak SEF?

3. What will you do differently in the future in regards to SEF?

4. What is next for science fair?

5. What unique resources have you acquired to support SEF?

6. During this study, you have been asked to comment on activities and lessons in your classroom that support SEF. What have you learned about yourself during this process?

Data Confidentially

All qualitative data collected were stored confidentially in a secure digital format using pseudonyms assigned by the researcher. All data were organized in folders labeled with participant pseudonym and additional folders within the participant folder for data types. Ownership of the pseudonyms for all participants were kept confidential by the researcher and stored in a digital format with password access privy to only the researcher. The collection of data for qualitative portion of this study was conducted over a two-month period or the length of one unit.

All data including documents, lesson plans, activities, or other de-identified examples were analyzed using a qualitative data analysis software, nVivo 10. Each initial interview, summative interview and any additional follow-up interviews were audio-recorded and transcribed using the Start-Stop Universal Transcription System or other comparable audio transcription system. Descriptive field notes were also written in a field

research notebook during the interviews, bi-weekly journals readings, observations, summative interviews, and follow-up interviews. Additionally, a tally sheet (Appendix E) was used to indicate the evidence of the types of basic and integrated science process skills as well as different levels of science inquiry throughout each process of data collection. Transcripts were analyzed using the qualitative statistical analytical software, nVivo 10. Additionally, a checklist of data collection events and artifacts (Appendix G) were maintained to act as a guideline, to assure the consistency of collection and add to the depth of the analysis.

Quantitative Research

Quantitative Research Question

The quantitative portion of this study sought to understand if a statistical relationship exists between science and engineering fair (SEF) participation and performance on the 2014 MST2 for fifth grade, and eighth grade standardized tests. More specifically, the study explored the following areas:

> While controlling for several school characteristics and student demographics (gender, ethnicity, socio-economic statics, and size of school) is there a difference in student achievement in schools that participate in science and engineering fair and those that do not participate in science and engineering fair?

De-identified mean scores were obtained from the MDE website and the Mississippi Statewide Longitudinal Data System (SLDS) through Mississippi Life Tracks. For additional description of data quality measures and security measure, see

Appendix J. Additional public data was obtained from the seven regional science fair directors in Mississippi. All schools eligible for participation in the study were coded by the researcher to include grade level and alphabetic descriptors (Table 3).

Quantitative Methods

The quantitative analysis included an assessment which utilized information for each school spanning multiple time periods. The general analytical approach involves multivariate statistical procedures that were used to examine the relationship between the establishment of science fair programs and shifts in student test scores during the academic years of 2004-2014. School district/grade combinations (i.e. fifth grade) are the unit of analysis. An ordinary least squares regression of students' mean MST2 science score on science fair policy and other school district/grade characteristics (gender, ethnicity, socio-economic statics, and size of school) was performed. Information provided by the Region V Mississippi Science and Engineering Fairs was used to construct these variables (Table 3). With the individual district/grade controlled for, observed associations between the science fair variables and test score measured the before-after effect of a school system implementing a science fair program. Year variables were included in the regression as well to adjust for time trends.

Table 3

Fifth grade school comparison MST2 scores and science fair participation data

School	Support Type	Years Implemented Support	Year Prior Support Type
5-A	Mandate	Aug 2013-May 2015	Aug 2011-May 2013
5-B	Mandate	Aug 2012-May 2015	Aug 2010-May 2012
5-C	Mandate	Aug 2012-May 2013	Aug 2010-May 2012
5-D	Choice	Aug 2006-May 2015	Aug 2000-May 2006
5-E	Mandate	Aug 2012-May 2015	Aug 2010-May 2012
5-F	Mandate	Aug 2013-May 2015	Aug 2010-May 2013
5-G	Choice	Aug 2013-May 2014	Aug 2011-May 2013
5-H	Choice	Aug 2014-May 2015	Aug 2012-May 2014
5-I	Mandate	Aug 2014-May 2015	Aug 2012-May 2014
5-J	Choice	Aug 2013-May 2014	Aug 2011-May 2013
5-K	Choice	Aug 2012-May 2015	Aug 2010-May 2012
5-L	Choice	Aug 2010-May 2015	Aug 2006-May 2010
5-M	Choice	Aug 2010-May 2015	Aug 2006-May 2015
5-N	Choice	Aug 2012-May 2015	Aug 2010-May 2012
5-O	Mandate	Aug 2012-May 2015	Aug 2010-May 2012
5-P	Mandate	Aug 2012-May 2013	Aug 2010-May 2012
5-Q	Mandate	Aug 2002-May 2003	Aug 1999-May 2002
5-R	Mandate	Aug 2012-May 2013	Aug 2010-May 2012
5-S	Choice	Aug 2009-May 2010	Aug 2006-May 2009
5-T	Choice	Aug 2010-May 2015	Aug 2006-May 2010
5-U	Mandate	Aug 2006-May 2015	Aug 2000-May 2006
5-V	Choice	Aug 2012-May 2015	Aug 2010-May 2012
5-W	Choice	Aug 2013-May 2015	Aug 2010-May 2013
8-A	Choice	Aug 2013-May 2015	Aug 2010-May 2013
8-B	Choice	Aug 2012-May 2015	Aug 2010-May 2012
8-C	Mandate	Aug 2013-May 2015	Aug 2010-May 2013
8-D	Mandate	Aug 2006-May 2015	Aug 2000-May 2006
8-E	Choice	Aug 2012-May 2015	Aug 2010-May 2012
8-F	Choice	Aug 2010-May 2015	Aug 2006-May 2010
8-G	Choice	Aug 2011-May 2014	Aug 2006-May 2011
8-H	Choice	Aug 2010-May 2015	Aug 2006-May 2010
8-I	Choice	Aug 2010-May 2013	Aug 2006-May 2010
8-J	Choice	Aug 2004-May 2015	Aug 2000-May 2004

The analysis focused on the comparison of schools against control schools. To control for variability among the sample population, demographics of all fifth grade schools (N=23) and all eighth grade schools (N=8) were analyzed. A difference-in-difference analysis was conducted in a single multivariate regression for individual schools. In each regression, students were the unit of analysis and student test score was the outcome variable. Each regression included students from two different schools: (1) a school which implemented a science fair (let's call it "school A") and (2) a control school which did not implement a science fair but that is otherwise demographically similar ("school B"). For each of these schools, students from two different points of time are included: (1) students enrolled during the academic year prior to the one in which school A implemented the science fair and (2) students enrolled during the academic year in which school A implemented the science fair.

Each regression model included three predictor variables: post, treat, and post*treat. Post is binary variable which equals 1 if the student's test score was measured after school A implemented the science fair (regardless of whether they attended school A or school B) and 0 otherwise. Treatment is a binary variable which equals 1 if the student attended school A (regardless of whether their test score was measured prior to or following science fair implementation) and 0 otherwise. Post*treat is an interaction between post and treat. If the B-value associated with post*treat is positive and significant, this indicates that school A improved relative to school B in student test scores during the period of implementation.

CHAPTER IV

ANALYSIS AND RESULTS

Qualitative Analysis

Review of Qualitative Focus

The qualitative focus of this research was to explore the common factors that contribute to an exemplary science and engineering fair teacher's actions to produce ISEF Finalists and/or Alternates. More specifically, this research explored the following questions:

1. Is there a relationship in the way an ESEFT values the relationship of science inquiry, science process skills and SEF? More specifically, the research explored the following questions:
    - Why do ESEFTs value science inquiry, science process skills?
    - Why do they value and implement science and engineering fair?
2. How do exemplary science and engineering fair teachers integrate science and engineering fair into the science curricula? More specifically, this focal area explored the following questions:
    - How do ESEFTs (exemplary science and engineering fair teachers) prepare students to participate in SEF?

- In what ways do ESEFTs include science process skills in the instruction they plan to prepare students to participate in science fair?
- In what ways do ESEFTs include elements of science inquiry-based instruction in the instruction they plan to prepare students to participate in science fair?
- In what ways do ESEFTs incorporate science and engineering fair into their regular classroom curricula beyond the period of instruction planned to prepare students to participate in science fair?
- What resources do ESEFTs perceive to support their success with SEF?

Modern Expectancy-Value Model Analysis

Using nVivo 10 qualitative statistical analysis, transcripts were analyzed to identify potential codes that align with the literature of the Modern Expectancy-Value Model. The specific codes chosen were intrinsic value, extrinsic value, utility value, academic performance prediction, motivational constructs, and cognitive constructs. In an effort to provide consistency to each code, a basic description for each code was created to provide a guideline for coding each transcript.

Code Descriptions

As previously mentioned, the codes indicated were chosen in alignment with the theoretical framework of the modern expectancy-value theory. Additionally, each code and descriptor was specifically selected to heuristically provide descriptions and search for patterns including similarities, differences, frequencies, sequencing, and causation

(Saldaña, 2009; 2015). The codes and descriptors as they relate to the modern expectancy-value model are outlined in Table 4.

Table 4

Initial Code Descriptions Correlated with Modern Expectancy-Value Model

Codes	Descriptor Guidelines
Extrinsic Value	money, scholarships, notoriety, patents
Intrinsic Value	personal value, belief, judgments, responsibility, enjoyment
Utility Value	how well the task relates to future career or goals
Academic Performance Perceptions	school evaluations, competitions, social comparisons, higher scores, deeper understanding
Motivation Constructs	mastery and performance, individual and situational interest, extrinsic/intrinsic factors
Cognitive Constructs	critical thinking, creativity, science process skills

Analysis of Coding

Upon completion of coding the interviews, teacher online responses, and follow-up interviews, analysis of patterns or trends were explored. Additionally, support from the theoretical framework for the patterns and trends were outlined. For example, in the table below the trend suggests that intrinsic value was the most common node, followed by academic performance, motivation, cognitive value, utility value and extrinsic value.

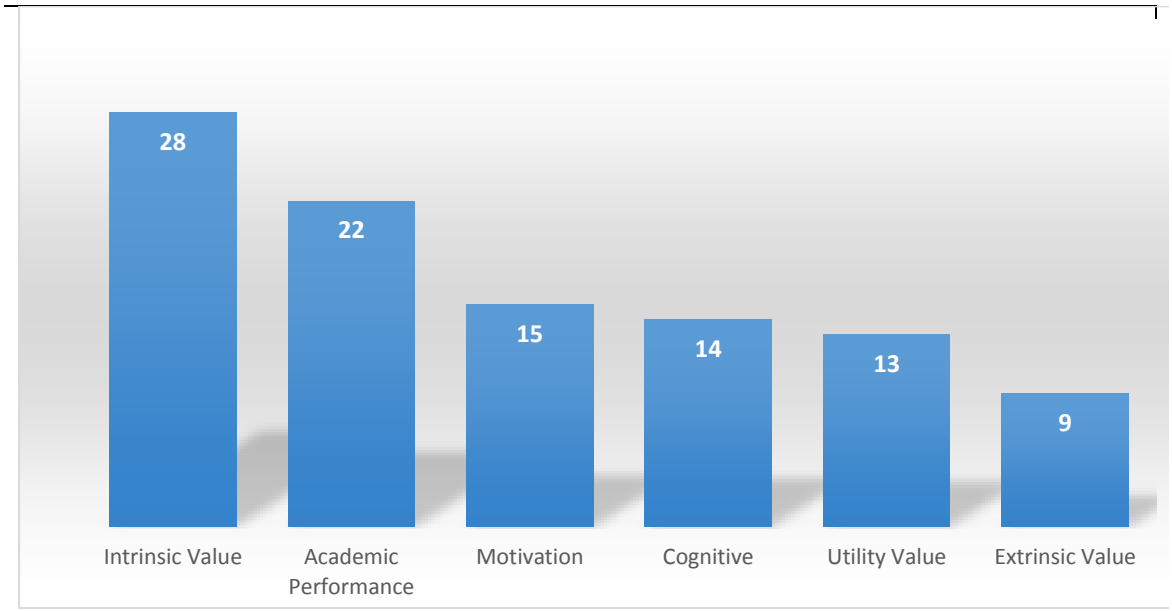

Figure 1. Comparison of occurrence of nodes (%) linking modern expectancy – value and science and engineering fair

Research by Eccles and Wigfield (2002) supports this trend. The research indicated that in the context of the Modern Expectancy-Value Theory, teachers who have a high intrinsic value (in this case for science inquiry and science and engineering fair), have the potential to translate this intrinsic value to their students. The students have the potential to have an overall increase in intrinsic value with the most successful students developing a higher intrinsic value for the content and process. As indicated by Eccles and Wigfield (2002), this often translates in to higher academic performance, motivational and cognitive values, utility value or future career goals. This finding is also similar to research by Korkmaz (2012), who identified those who become intrinsically vested in science and engineering fair projects, whether low-achievers or high-achievers, seem to internalize the utility value of science and engineering fairs.

In the next phase of analysis, a word frequency query from all transcripts was conducted. The summary results indicated obvious high incidence of *science, students, fair, inquiry, participate, process, like, see, use and think*. The words *science, students and fair* are obvious choices for high word frequency. However, *participate, think, process, like, see and use* are all words that indicate expectancy-value relationships (Eccles, 1998). For example, if an individual likes an activity or idea, they are more likely to participate in the process, resulting in the use of higher order thinking skills. Students could actually use the content learned that will add to the intrinsic value of accomplishing the goals.

After this initial analysis, one additional node was added, Cost. As indicated by Eccles and Wigfield (2002), cost is associated with the negative aspects of "engaging in a task" (p. 120). In particular, performance anxiety, fear of failure or success, and amount of time and effort required by the teacher and student are negative associated costs that can decrease the value of science inquiry and science and engineering fair project. In an effort to account for these costs, additional child nodes were added to increase the depth of explanation. The child nodes for cost (performance anxiety, fear of failure or success, and amount of time and effort) that aligned with the modern expectancy-value theory were added, and the interviews and follow-up interviews were recoded.

Additionally, child nodes for academic performance prediction and utility value were also added for increased depth of explanation of the parent nodes. I determined that a pattern of positive and negative viewpoints were prevalent in relation to academic performance prediction. Therefore, the child nodes of positive and negative were added to academic performance prediction. In an effort to develop a linkage between utility

value and intrinsic value, additional child nodes were needed. It was determined based upon the theoretical framework that the child nodes of career goals and tasks would be added to utility value. Lastly, to explore more in depth the motivational values as they relate to science inquiry and science and engineering fair, the child nodes of achieve, participate, and success were added. Once again, all of these additional nodes and child nodes are supported by the literature found on the Modern Expectancy-Value Theory (Eccles & Wigfield, 2002). The new coding and descriptors are outlined in Table 5 below.

Table 5

Relationship of Recoded Descriptions with Modern Expectancy-Value Model

Codes	Descriptor Guidelines
Extrinsic Value	money, scholarships, notoriety, patents
Intrinsic Value	personal value, belief, judgments, responsibility, enjoyment
Utility Value	*career goals, tasks*
Academic Performance Perceptions	school evaluations, competitions, social comparisons, higher scores, deeper understanding, *positive and negative*
Motivation Constructs	mastery and performance, individual and situational interest, extrinsic/intrinsic factors, *achieve, participate, success*
Cognitive Constructs	critical thinking, creativity, science process skills
Costs	*performance anxiety, fear of failure or success, and amount of time and effort*

Note: new nodes and child nodes italicized.

In an effort to explore linkages between codes, several matrix queries were explored. A matrix query between intrinsic value and utility value resulted in highly correlated linkages. The matrix query in Table 5 indicates a potential linkage between utility value nodes (career goals and tasks) and enjoyment, personal value and responsibility. Additionally, a definite difference is evident in the relationship between judgment and belief as related to career goals and tasks. The analysis indicated that judgment and belief have more of an influence on tasks than on career goals.

Emerging Themes

Upon conclusion of the data analysis several themes emerged that directly linked to the modern expectancy-value theory in terms of what the teachers believed. These themes of teachers beliefs included: (1) teachers considered intrinsic value as the most important factor in the motivation and value of science inquiry and science and engineering fair, (2) teachers established a direct connection between the engagement in science inquiry and/or science and engineering fair and future career choices, (3) teachers saw evidence of an increase in academic aptitude is expected when students have internalized the value of science inquiry and science and engineering fair, (4) teachers agreed that although specific costs are evident, the benefits far outweigh the costs, and (5) teachers indicated a linkage between utility value and the intrinsic values of personal value and enjoyment.

Teachers Believed in the Intrinsic Value of Science Inquiry and Science and Engineering Fair.

McComas (2011) indicated that students who seem to gain the most value from science inquiry and science and engineering fair projects are those who become personally vested in the value of the experimental design and content. If a person, teacher or student, has a vested interest of the science inquiry activity they have the potential to obtain maximum intrinsic value. This was evident in all ESEFT transcripts. For example, Ms. Leslit indicated that:

> …students have to be vested in it, ya know what I mean. They have to know that what they are doing has a purpose. The students who are most successful are the

ones who believe in it, love it, live it, and breathe it. In the same sense, if I don't live it and breathe it, they won't either.

Ms. Leslit indicated that it is possible for a student to increase intrinsic value of science and engineering fair through the perception of positive intrinsic value modeled by the ESEFT. She believed that the student investment was key to success of a student understanding the value of the science inquiry through the science and engineering fair process.

This is also evident in Ms. Mahoney's description of the key to promoting the value of science and engineering fair in students. Ms. Mahoney suggested that "I'm willing to give them time to pursue something that is specific to what they are interested in, because I think that is the key..." and "let them focus on something they really want to do…". When speaking about a particular student, she indicated "he was vested, he loved it."

So by performing engaging activities designed to support science and engineering fair, they internalize the value for future use. If the teachers convey the importance of the NOS through the frame of the science and engineering fair projects, this could potentially lead to increased intrinsic value in the NOS through science and engineering fair projects for students.

Teachers Believe in the Incorporation of Strategic Engagement Opportunities to Support STEM Career Choices

The teachers also indicated that the inquiry activities they implemented in the classroom are directly designed to increase the ability of students to obtain usable skills for their future career choices. The teacher participants specifically expressed that the

students who choose to participate in science and engineering fairs often matriculate to careers in the category of their research or other similar STEM field. Ms. Tyran expressed that:

> my babies who go to ISEF started forming their ideas for their research in the middle grades. This is where it started. They had a vision. One of my former students knew the catfish farmers were having problems with pollution in their water. He wanted to solve the problem. He had learned how in his classes. He came to me, then I hooked him up with a scientist and guided him through it. Now he is majoring in wildlife and fisheries. It's amazing to see how the vision becomes a reality.

As Ms. Tyran indicated that experiences in science and engineering fair from her class influenced her student's career paths. Specifically, a student's ability to place value in the quality of a science and engineering fair project matriculated to a major in wildlife and fisheries and a potential career in a STEM field.

Ms. Mahoney also indicated that she has witnessed "proof in the impact" of science and engineering fair as a tool for providing an environment where students can become intrinsically vested and potentially lead to future STEM degrees. Ms. Mahoney enthusiastically described examples of these particular students who:

> After Hurricane Katrina, decided…to teach wasps to go and seek cadavers. It was the ability to create that thought process…that landed her a job in forensic research in Iowa. Another group of boys…did a mind storm robot…that could

> open and close blinds. One of them is now a cardiologist who uses the Da Vinci robot to do heart surgery.

Ms. Mahoney expressed that "not only were they interested in science, but it gave them critical thinking, the problem solving". She also shared that she believed that it was "the experiences the science and engineering fair process, the skills learned, the presenting of their projects that really opened up their eyes to what they could be…a scientist".

This same sentiment was also highlighted by Ms. Clane. Ms. Clane spoke directly to the effect of intrinsic value on of science and engineering fair on underprivileged populations. She shared:

> You know I'm poor, my people are poor, my community is poor, my school is poor. I would say 99.9% of our students don't leave (the) county. As they do their projects, they begin to visualize themselves as a scientist. Something they have only seen on TV and in books or the doctor office. They internalize the value of the project. This is what happened with many of my students. I have one that is now a doctor, one that is an engineer, one that is an extension agent…and all are products of my science and engineering fair program. They will tell you that is why they are successful scientists. It gave them meaning, a purpose, a direction. Now they are my judges.

Ms. Tyran, Ms. Mahoney and Ms. Clane all believed that their students chose STEM careers because of the intrinsic value obtained while conducting science and engineering fair projects. Therefore, the personal investment of a student in science inquiry and science and engineering fair has potential to lead to choices in STEM careers.

Teachers Believe in the Relationship of Intrinsic Value, Motivation, and Pathway to Increase Academic Aptitude

The data analysis indicated an overlap with the codes intrinsic value, motivation and academic aptitude. This means that whenever a teacher talked about these topics, each did so within the frame of the others. The nodes of motivation, academic performance and engagement were continuously intertwined and were coded all three ways. For example, in the initial interview with Ms. Jude, the data indicated an overlap in intrinsic value, motivation and academic aptitude. In the follow-up interview, I asked her to clarify what she meant by students who participate in science inquiry often have the best grades. Ms. Jude indicated that:

> Students who love science and engineering fair and inquiry, love the labs in class. It is probably reverse as well. They are the leaders. You can see it in their eyes. They love the challenge of the unknown…the unexplored…the unanswered. They question it all. The skills they develop…critical thinking, presentation, resolving…the passion is there. They are my best students and strive to succeed academically and do.

Ms. Jude concluded that the intrinsic value motivated the students to excel, resulting in higher academic achievement.

This relationship also existed in a description of one of Mr. Anderson's greatest student successes. Mr. Anderson shared that:

> …my state winner really stands out to me as perfect example of a student who has been greatly impacted by the science and engineering fair project. She loves the whole process. I mean she found something she was interested in, researched it, is

> internationally recognized for her research, and has chosen to become an engineer. How much better can that be? She is very driven. She has top honors at the school. She was not always this way, but I believe science fair was instrumental in her transformation. And this is only one example.

Not only did Mr. Anderson's student have intrinsic value, motivation, and increase academic aptitude, she was choosing a STEM career as well. This could be an additional overlap of codes.

Ms. Jude and Mr. Anderson both agreed that intrinsic value could lead to motivation and academic achievement. However, the analysis also indicates that the potential for increase in intrinsic value of science inquiry and science fair is intertwined with more than just motivation and increased academic aptitude.

Teachers Believe That the Benefits Far Outweigh the Costs

When exploring the costs of participation in science inquiry and science and engineering fair, there were several common issues that were identified: perception, time, money, and support.

As a teacher, Ms. Tyran suggested that quite often support is lacking for science inquiry and science and engineering fair in the classroom. She indicated that:

> to do inquiry at the basic level it takes money. Investigation in science take money. In…our school districts are so rural and underfunded, the money for these investigations often comes from our pockets. The teachers. I am not going to let my babies go without. They are our future.

Additionally, Ms. Leslit indicated that support, time, money and perception are often intertwined:

> my administration is very supportive as long as it does not cost them any money and it brings notoriety to the school…makes them look good you see. That is what it is all about with the administration. They have recently moved me to the high school in an effort to get more high school students involved in science and engineering fair. This is definitely a great thing. I am able to work with all of the teachers and students now. But that means more work for me too.

Ms. Mahoney suggested that "a lot of teachers just don't want to do the work". She also suggested that this often leads to opposition from teachers, parents and sometimes students. However, Ms. Mahoney as well as all of the other ESEFTs suggest that time is the greatest cost. Most importantly, all teachers emphatically expressed that all of the benefits of engaging students in science inquiry and science and engineering fair activities, like increased academic aptitude and the ability to "do" (Ms. Tyran) science far outweigh the costs. Ms. Tyran indicated that the benefit of "pride in oneself for designing and presenting their own far outweighed the costs".

The idea that the benefits of conducting a science and engineering fair experiment far outweigh the costs was emphatically expressed by all ESEFTs. Hansen (1983) indicated that planning and support from parents and fellow teachers can often alleviate the personal time and other associated costs. As indicated by Mr. Anderson, support by teachers, parents, and other community members can "sometimes make it so you don't see all the cost of helping students with their science and engineering fair projects".

Teachers Believe in Linkage Between Intrinsic and Utility Value

In the data analysis, a matrix query indicated a relationship exists between intrinsic value and utility value as described in the modern expectancy-value theory (Eccles and Wigfield, 2002). First, the query indicated a linkage between utility value and the intrinsic values of personal value, responsibility and enjoyment. This is in agreement with previous research where subjective tasks correlate with interest or enjoyment value and personal value (Eccles, et.al, 1998). However, research does not indicate that responsibility is linked motivational values rather than utility value. However, research has suggested that motivational value is connected to utility value. Therefore, this could propose a potential sequence of value among utility value, the intrinsic value of responsibility and motivational values. For example, Ms. Leslit shared the following insight:

> It is my responsibility to share with students the importance of the inquiry activities in relation to their future careers. If they value what they are learning, they might could see themselves, ya know, becoming a scientist, engineer, nurse, doctor, and such. They will become responsible citizens. It is my hope that the science and engineering fair project, and other inquiry experiences I provide for my students will do just that. These experiences have motivated my babies to become doctors, plant geneticists and more. I am so proud of them.

Ms. Leslit understood that students who value the knowledge gained when conducting the inquiry tasks, in particular the science and engineering fair project, are often influenced to choose careers that relate to the tasks. Although Ms. Leslit was quick

to point out that "winning competitions" or competitiveness was not her focus she indicated that success through "winning science and engineering fair competitions and ease of understanding of higher order skills" increased their motivation, as well as sense of self-worth and responsibility for their future. The teachers indicated that the students because the students developed a deep intrinsic value for science inquiry activities and science fair, they were willing to "put in the work required" (Mr. Anderson). Ms. Tyran suggested that the students "visualized the tasks and completed the tasks knowing they would use the tasks later in life".

Ms. Leslit, Mr. Anderson, and Ms Tyran described the relationship between intrinsic value and utility value as a natural progression. If a student is vested in the activity or project, they will work hard to achieve their desired goals.

Focal Areas

Exemplary science and engineering fair teachers have a strong belief in the value of science and engineering fair as a teaching strategy for developing deeper learning experience for their students. As evident in the teachers beliefs discussed previously, all ESEFTs value the use of SEF, but how do ESEFTs implement the SEF in the classroom? There are several areas of focus discussed by ESEFTs that promote the success of SEF in the classroom: (1) preparation of students for participation, (2) inclusion of science process skills in preparation for SEF, (3) inclusion of science-inquiry based instruction, (4) incorporation of SEF into curriculum and beyond the classroom, and (5) resources to support SEF.

How Do ESEFTs Prepare Students to Participate in SEF?

When considering teacher preparation of students for science and engineering fair participation several areas of questioning where highlighted and analyzed. First, a general consensus definition of ESEFTs was explored. Next, the ESEFTs personal experience with SEF was needed to potentially determine motivation for incorporation of SEF into the curricula. The researcher also explored the ESEFTs vision or perception of a high quality SEF project, activities that promote SEF in the classroom, ingredients of success, and collection of supporting documents.

A general consensus of all six ESEFTs defined an ESEFT as a teacher that has had success in promoting and implementing SEF practices in the classroom. Only one teacher, Ms. Clane, suggested that an ESEFT should have had students that were successful in obtaining an International Science and Engineering Finalist position. The other ESEFTs indicated that having a student "achieve a deeper understanding through the framework of SEF" (Mr. Anderson), and potentially moving up from "local to regional to state to international competition was just a bonus" (Ms. Leslit). This suggests that teachers were more concerned with providing the best possible experience for their students to explore the nature of science, and less concerned with their own accolades.

Of the six ESEFTs interviewed, most indicated that their first experience with science and engineering fair projects stemmed from science demonstration projects they personally conducted in primary school. This is similar to other research (Blenis, 2000; Callison, 2014; Czerniak & Lumpe, 2006; Tillman, 2011). Ms. Leslit and Ms. Clane both indicated the thrill of conducting demonstrations "excited me about science", but did not

provide a real opportunity to experience NOS. Mr. Anderson said that he thought "solar system project, tornado bottles, and fruit batteries" were science fair projects initially. Because of their lack of the correct format of a science and engineering fair projects in their personal school years, all ESEFTs indicated the need for students to conduct "real" science and understand the NOS or what a scientist does in their daily career as the single most reason for including and promoting SEF in their classrooms.

Each ESEFT indicated the importance of preparing students to create high quality projects. However, each had slightly different perceptions of what was required to consider a SEF project as a high quality projects; student engagement, connection to real world problems such as "purifying water for 3rd world countries" (Mr. Anderson), and "scientifically literate" about the content (Ms. Clane and Ms. Mahoney). When the ESEFT's were asked to explain how they prepare their students for designing the science fair display, all were in agreement that the design of the display board really needed to "tell the story" (Ms. Clane).

Each ESEFT was reluctant to provide clues to how they prepare the students to design the SEF displays. So, I asked each ESEFT to provide an example of a high quality science fair display. Again, all ESEFTs hesitated to provide examples. They also indicated that they hesitate to show students examples of science fair boards. All indicated that each science and engineering project display should be indicative of each individual research project. Mr. Anderson did share an example of a de-identified science and engineering fair display that he considered of high quality (Figure 2).

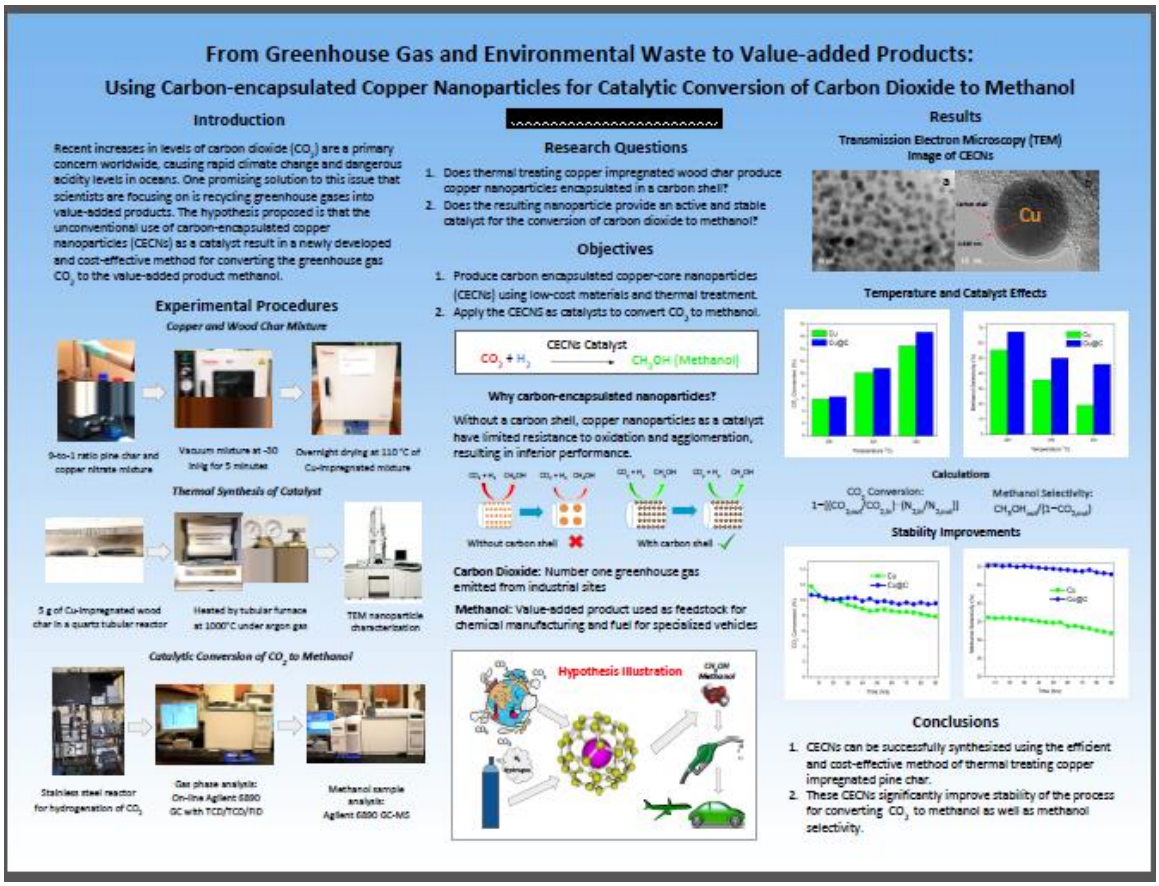

Figure 2. Student example of high quality SEF project submitted by Mr. Anderson.

Mr. Anderson indicated that the SEF display arrangement above (Figure 2) contained "many descriptive pictures, an overall generally pleasing flow, but most of all a topic and research that had a direct impact on the world". This theme was reiterated throughout every ESEFT interview. So to prepare his students to create displays like this, Mr. Anderson indicated that he teaches each part individually in small inquiry activities or labs. These labs build one upon the other. As the science process skills develop, the students begin to understand the NOS. Mr. Anderson said that the result of a "methodical build of science process skills that include "telling the story" through descriptive analysis and presentations as seen in the display in Figure 2, leads to success in the mastery of

science inquiry, science process skills and what it takes to be a scientist or the nature of science.

Therefore, three main themes seemed to resonate in the interviews and subsequent follow-up interviews. First, the SEF had to be relevant to student. Second, the SEF had to have an impact on the community. Lastly, the SEF must improve the "greater good for humanity" (Ms. Clane). Mr. Anderson indicated that a high quality SEF project must be "highly applicable". It is these key ingredients that all ESEFTs quoted as "essential to the quality of an advanced SEF project" (Ms. Mahoney). However, three of the ESEFTs, Mr. Anderson, Ms. Clane and Ms. Mahoney, added another layer to what constitutes a high quality SEF project: data. They were in agreement that data analysis and the "story of the data" (Ms. Clane and Ms. Leslit) is the single most important factor in determining whether a SEF is ready for higher levels of competition. Once again, both stressed that competitiveness was not their focus, but they would provide support for increasing the rigor of the project to increase the opportunity for a student to succeed in competition. Ms. Clane indicated that data was like "gold…it's so precious". She based this on training she received as a Society for Science and the Public (the foundation that hosts ISEF) fellow. She further described that "statistics behind the data is what can take that project to the next level". In a follow-up interview, Ms. Clane continued to say that "students just can't say this and say that with nothing to show. Integration of data…the student's learning and using of basic statistics...running a program to enter data…they just amaze me".

In What Ways Do ESEFTs Include Science Process Skills in the Instruction They Plan to Prepare Students to Participate in Science and Engineering Fair?

The focus on the mastery of science process skills was evident in all ESEFT classroom observation and throughout the interview process. From the classroom observation using the science classroom observation rubric to the transcripts from the interviews, to the biweekly journals it was very evident ESEFTs focus on the mastery of science process skills including integration of information through problem solving. In an nVivo 10 word analysis of transcripts, the occurrence of science process skill key words were evident (Figure 3).

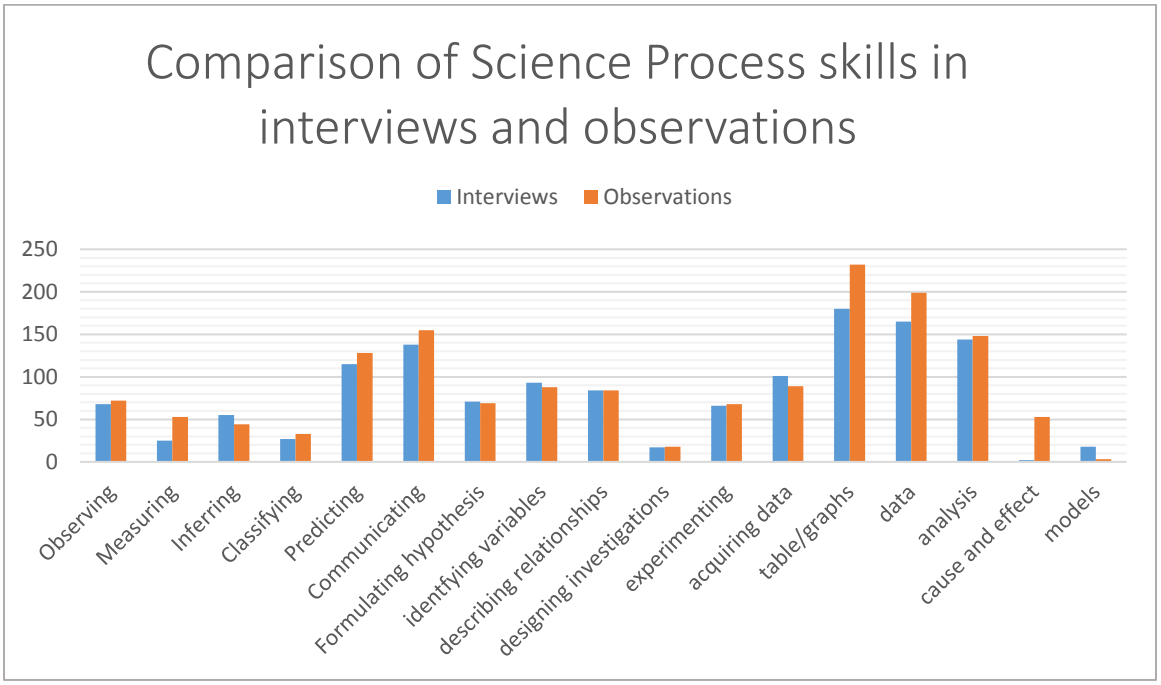

Figure 3. Comparison of word count for science process skills in observations and interviews.

The specific science process skills that were the most numerous in the interviews and the observations were: predicting, communicating, table/graphs, data and analysis.

This indicates that ESEFTs are focused more on integrated science process skills than basic process skills. They are providing experiences for students to practice the higher level science process skills. Also, each ESEFT had their own unique way of integrating activities that promote SEF through science inquiry and science process skills in the classroom. Mr. Anderson, Ms. Mahoney, and Ms. Leslit indicated that all inquiry activities or laboratory activities culminate in a student's understanding and practice of science process skill and the research process needed to complete a SEF.

Ms. Mahoney completed weekly lessons that science process skills such as "observing, measuring, calculating and justifying with the sole purpose of the specific activity or laboratory investigation focusing on inquiry and the opportunity for students to "practice those essential science skills". Ms. Clane and Ms. Jude first approached the scientifically literate aspect for search and discovery of potential ideas that culminated with open-ended inquiry of the formulation of an idea, focusing on that idea, developing a test or experiment, implementing that experiment, and explanation of results. They followed this methodology through out every inquiry activity in her classroom focusing on science process skills to promote science inquiry.

These examples directly relate to what the ESEFTs indicated as essential to a high quality SEF project. As evident in the descriptions provided, the ESEFTs daily lessons and interviews included many discussions of multiple of teaching strategies that lay the foundation for the necessity of science process skills to progress toward a high quality SEF project.

In What Ways Do ESEFTs Include Elements of Science Inquiry-Based Instruction in the Instruction They Plan to Prepare Students to Participate in Science and Engineering Fair?

"Every day and every way" was the response received from Mr. Anderson. He was alluding to the incorporation of science inquiry-based instruction and preparation of students to participate in SEF. This was mentioned by all six ESEFTs. Ms. Mahoney explained that her parochial school in May of 2016 "rewrote the science standards to include science inquiry and science process skills in every standard of the science curricula". Although I was not privy to the complete science standards for the parochial school, the use of science inquiry and science process skills was evident in all lesson plans submitted. In each lesson, she describes the standard assessed, content explained, science process skills to be mastered, and application of the skill in a laboratory setting. In a follow-up interview, Ms. Mahoney was asked to expand on how this lesson plan format with inclusion of science inquiry and science process skills promoted or prepared students for SEF. Ms. Mahoney replied:

> Well I believe a student would hear and write, but when they see and they touch…that brings them all together…they understand the whole concept. For example, in Chem 1 students memorize the word, oxidation. When (they begin) in Chem. 2, they can't tell me what it means…but when they see it (in the laboratory)…it brings everything together in a usable form.

Ms. Mahoney understanding of the value of applicability of content, or skills that must be taught and the translation of those skills into viable tools for real world problem solving is in direct parallel with Lederman's (1999) outlook for students' perceptions of NOS. Therefore the inclusion of inquiry-based activities that incorporate incremental practice

of aspects of NOS could be considered essential to the developmental understanding of the processes involved the science and engineering fair project.

In What Ways Do ESEFTs Prepare for the Inclusion of SEF into Their Regular Classroom Curricula and Beyond the Period of Instruction Planned to Prepare Students to Participate in Science and Engineering Fair?

Each ESEFT a variety of strategies for inclusion of SEF into the regular classroom and beyond. Ms. Mahoney, Ms. Leslit, and Ms. Tyran all indicated that students must complete all but the experiment itself in the classroom. All indicated that the SEF fits perfectly into the first standard of every science curriculum, which is the "Inquiry Strand" (Figure 3-4) from kindergarten- eighth grade and in all high school science courses.

FIFTH GRADE

CONTENT STRANDS:

Inquiry **Life Science**
Physical Science **Earth and Space Science**

COMPETENCIES AND OBJECTIVES:

INQUIRY

1. **Develop and demonstrate an understanding of scientific inquiry using process skills.**

   a. Form a hypothesis, predict outcomes, and conduct a fair investigation that includes manipulating variables and using experimental controls. (DOK 3)
   b. Distinguish between observations and inferences. (DOK 2)
   c. Use precise measurement in conjunction with simple tools and technology to perform tests and collect data. (DOK 1)
      - Tools (English rulers [to the nearest one-sixteenth of an inch], metric rulers [to the nearest millimeter], thermometers, scales, hand lenses, microscopes, balances, clocks, calculators, anemometers, rain gauges, barometers, hygrometers)
      - Types of data (height, mass, volume, temperature, length, time, distance, volume, perimeter, area)
   d. Organize and interpret data in tables and graphs to construct explanations and draw conclusions. (DOK 2)
   e. Use drawings, tables, graphs, and written and oral language to describe objects and explain ideas and actions. (DOK 2)
   f. Make and compare different proposals when designing a solution or product. (DOK 2)
   g. Evaluate results of different data (whether trivial or significant). (DOK 2)
   h. Infer and describe alternate explanations and predictions. (DOK 3)

Figure 4. Fifth grade Inquiry Strand Mississippi Department of Education.

Eighth Grade

CONTENT STRANDS:

Inquiry **Life Science**
Physical Science **Earth and Space Science**

COMPETENCIES AND OBJECTIVES:

INQUIRY

1. **Draw conclusions from scientific investigations including controlled experiments.**

    a. Design, conduct, and analyze conclusions from an investigation that includes using experimental controls. (DOK 3)
    b. Distinguish between qualitative and quantitative observations and make inferences based on observations. (DOK 3)
    c. Summarize data to show the cause and effect relationship between qualitative and quantitative observations (using standard, metric, and non-standard units of measurement). (DOK 3)
        - Tools (e.g., English rulers [to the nearest one-sixteenth of an inch], metric rulers [to the nearest millimeter], thermometers, scales, hand lenses, microscopes, balances, clocks, calculators, anemometers, rain gauges, barometers, hygrometers, telescopes, compasses, spring scales, pH indicators, stopwatches, graduated cylinders, medicine droppers)
        - Types of data (e.g., linear measures, mass, volume, temperature, area, perimeter)
        - Resources (e.g., Internet, electronic encyclopedias, journals, community resources, etc.)
    d. Analyze evidence that is used to form explanations and draw conclusions. (DOK 3)
    e. Develop a logical argument defending conclusions of an experimental method. (DOK 3)
    f. Develop a logical argument to explain why perfectly designed solutions do not exist. (DOK 3)
    g. Justify a scientist's need to revise conclusions after encountering new experimental evidence that does not match existing explanations. (DOK 3)
    h. Analyze different ideas and recognize the skepticism of others as part of the scientific process in considering alternative conclusions. (DOK 3)

Figure 5. Eighth Grade Inquiry Strand Mississippi Department of Education.

Ms. Clane commented that her whole class, a research class, was "based on designing and implementing research" for the SEF project. She incorporates the inquiry strand from all high school science courses in her research classroom. However, Mr. Anderson and Ms. Leslit indicated that they really struggled to assist students with SEF projects in the regular classroom. Mr. Anderson stated that, "class size and the push to succeed on the state test" as factors that affected incorporation of SEF in his classroom.

However, he quickly commented that his afterschool program for research in science provides assistance with SEF.

Ms. Clane's story was unique. Ms. Clane expressed a deep desire to include SEF in all science classes. She too agreed with the other ESEFT's that support for inclusion of SEF resides in the first strand of all science curriculum in the state. However, she expressed that:

> inclusion in the curriculum means much more than just in the classroom. If all teachers were using science fair as a tool for teaching the nature of science, then research classes would be in every school. There would be no need for individual research courses. All students would have the opportunity to engage in deeper learning experiences. Wouldn't it be lovely if all students in the state received? that opportunity to blossom and see themselves as a scientist. Oh yes, it should be more than just part of the curriculum.

Ms. Clane's proclamation for the effectiveness of SEF as the essential teaching strategy for facilitating students through the inquiry strand could be perceived as a strong argument for the implementation of science and engineering fair in all science classrooms. The potential of processes involved in developing, implementing and presenting a science fair project has the potential to lead to a deeper learning experience for all students.

What Resources Do ESEFTs Perceive to Support Their Success with SEF?

ESEFTs indicated that support is found in many different forms. Each ESEFT elaborated on support in terms of funding, administration, physical space, curriculum requirement and others. Overwhelmingly, each ESEFT indicated that administration was

most essential form of support needed for success with SEF. Ms. Clane shared that having a "supportive administration as the key ingredient to other support…student, parent, community, and such".

Teachers also named other types of support. Ms. Mahoney, who indicated that she was "very blessed to have such a wonderful principal", was adamant that administrative support was key to success with SEF. However, she also indicated that parental and community support were essential in her parochial school environment. She said, "They (parents) are wonderfully supportive from judging to everything else." She also indicated that access to experts to support the advancement of students to the next level was a necessary component of the success of the SEF program. She indicated that "all I have to do is call on any community member…they have been so supportive of so many of my SEF students…numerous". Administrative, parent and community support were parts of the success for all of the ESEFTs. Support was seen as the key to decreasing the stress and other costs of SEF.

One particular emphasis on support was the incorporation of a research programs or classes to support the students during the SEF process. Two ESEFTs have implemented different versions of research programs in their school systems. First, Ms. Clane, a former SSP fellow, received a large grant for her rural school to implement an after school and summer program for science research and exploration. This directly supported the SEF program for her school district. Upon the completion of the 4-year, $35,000 grant, Ms. Clane approached the principal of the high school to allow her to continue the research program as a class in the high school. She has several research classes that solely focus on scientific research and investigation. Ms. Clane indicated that

support of administration, parent, teacher and community all have significant contributions to the success of her program.

Second, Mr. Anderson, along with another fellow teacher, saw the need to have a research program in their school. He indicated earlier that he did not have time or support to incorporate SEF into the classroom curricula because of the "push to score well" on the standardized science assessments. So, he approached the principal who granted support and minor funding to create an afterschool program that focuses on developing a student research program called "*Excaliber*". Mr. Anderson explained that his classrooms are overflowing with students. They are so full that physical space needed to conduct research is often a problem. The *Excaliber* program alleviated the physical space issue and was embraced by teachers, administration, parents and community members as a vital tool in the development of SEF project of high quality.

Therefore, support was seen as essential and key by all ESEFTs. Support in the form of administration and community members were considered and integral ingredient in the success of the SEF in their schools. Additionally, incorporation of SEF in the classroom wasn't always feasible. Therefore, ESEFTs found other ways of support through creating opportunities for incorporation of SEF through research class and afterschool programs.

Quantitative Analysis

Overview of Quantitative analysis

This portion of the study attempted to establish a statistical relationship between science and engineering fair (SEF) participation and performance on the MST2 for fifth grade. This process of analysis is two-fold. First, the sample was narrowed based on

available data, school characteristics and shifts in state level curricular revision for science (change in curricula in 2010) and implementation of the standardized MST2 assessment in the year 2010 to include only fifth grade (N=8). Next, we determined if there was a difference in student achievement in schools that participate in SEF while controlling for several school characteristics and student demographics (gender, ethnicity, socio-economic statics, and size of school).

Quantitative Analysis

The quantitative analysis employed both a self-comparison of academic growth in science for a particular school, and a comparison of each school to a control school. The quantitative research sought to compare fifth grade and eighth grade. As indicated in the research methodology, a control was selected to match the demographic information (gender, ethnicity, socio-economic statics, and size of school) of as many schools as possible. Of the available data from schools in this study (N=32) eight fifth grade schools were identified to compare demographically with one of the selected control schools. This initial sample was reduced to ensure data quality align with the research questions.

In 2010 the Mississippi State Department of Education adopted a new curriculum and new standardized assessment in which a portion assessed inquiry. The reduction of the data set removed schools which exhibited test scores from two different assessments for pre-and post-implementation of science fair. This was an essential element of maintaining internal validity within the experimental design. Additionally, schools removed in which both pre-and post-assessments represented by the pre-2010 science standardized test. Publicly available data for this test did not include a break down for inquiry-based items.

To assess the internal validity of the data, the population was analyzed for gender, ethnicity, socio-economic statics, size of school. A confidence interval was calculated to ensure the means fall within a 95% confidence interval. The resulting eight schools, all fifth grade, were similar in demographics to the one of the four area schools who did not participate in science and engineering fair (Table 6). The largest variation in these data can be found under economically disadvantaged (1.43-100%) because the sample schools included representatives on both ends of these spectrum, we have included a discussion of these variables in the analysis.

Table 6

Demographics of fifth grade School Treatment and Control Choice (N=8)

School Code	Enrollment	Male (%)	Female (%)	Econ. Disadv. (%)	Special Ed (%)	Asian (%)	Black (%)	Hispanic (%)	White (%)
5-B	408	51.96	48.04	3.92	14.71	0.74	91.18	1.23	6.86
5-G	407	53.07	46.93	100	7.62	0.49	79.36	1.23	18.92
5-J	149	44.3	44.7	4.7	16.11	0	89.26	0.67	8.05
5-K	402	55.22	44.78	100	14.93	0.25	35.82	1.74	61.94
5-N	702	51.71	48.29	100	14.53	0.28	97.01	0.71	1.99
5-P	400	52	48	5	13.75	1	87.5	2.25	9.25
5-R	302	55.96	44.04	3.64	14.57	0.66	96.69	0	2.32
5-U	350	54.57	45.43	1.43	14.29	3.14	65.43	1.43	29.14
Control	410	53.17	46.83	99.51	17.07	0	14.15	0.73	83.66

*Data obtained from Statewide Longitudinal Data System (SLDS Reporting Service, https://lifetracks.ms.gov.

Table 7 includes a list of the number of student observations and corresponding control observations during the designated time periods of pre and post implementation.

Table 7

Student enrollment, observations and control observations

School Code	Enrollment	Observations	Control Observations
5-B	408	150	137
5-G	407	667	140
5-J	149	48	140
5-K	402	291	137
5-N	702	129	137
5-P	400	122	137
5-R	302	1018	137
5-U	350	296	137
Control	410		

These characteristics (gender, ethnicity, socio-economic statics, size of school classification as rural or urban, and location) were controlled for in the regression model and multivariate model evaluating the level of implementation. Tables 8-15 describe the difference-in-difference results for the overall science scores on the MST2 for each school (Table 6 and 7) with choice of participation in science fair in versus the control.

When analyzing Table 8, the student scores for both A and B schools were significantly higher ($p<.01$) after implementation of science and engineering fair. Student scores for school A were significantly lower ($p<.001$) than that of the control before and after implementation. School A did not improve relative to the control school.

Table 8

Difference-in-Difference Results for Science Score 5-B versus Control School

	B	SE
Intercept	150.16923***	1.54223
post	6.30299**	2.12737
treat	-5.6405***	1.61263
post*treat	0.58442	2.28647

Note: **p<.01, ***p<.001

In the analysis of Table 9, there was no statistical difference between pre and post scores for both A and B schools. Student scores for school A are significantly lower ($p<.001$) than that of the control before and after implementation. School A did not improve relative to the control school.

Table 9

Difference-in-Difference Results for Science Score 5-G versus Control School

	B	SE
Intercept	156.47222***	1.27422
post	0.11601	1.82833
treat	-8.16486***	1.36992
post*treat	1.21565	2.04109

Note: ***p<.001

Analysis of results in Table 10 indicate that student scores for school A were significantly lower than that of the control before and after implementation. Student scores for school A were significantly lower ($p<.01$) than that of the control before and after implementation. School A did not improve relative to the control school.

Table 10

Difference-in-Difference Results for Science Score 5-J versus Control School

	B	SE
Intercept	156.47222***	0.99612
post	0.11601	1.42929
treat	-5.22222**	1.79578
post*treat	-0.30351	2.95645

Note: **p<.01, ***p<.001

In table 11, student scores for both A and B schools were significantly higher ($p<.01$) after implementation. Student scores for school A were *not* significantly lower than that of the control before and after implementation. There was no difference between schools. This is the only school that had student scores that were significantly lower than the control before and after implementation. This difference is addressed in the discussion in Chapter 5.

Table 11

Difference-in-Difference Results for Science Score 5-K versus Control School

	B	SE
Intercept	150.16923***	1.40448
post	6.30299**	1.93735
treat	2.71737!	1.62279
post*treat	-3.18959	2.38144

Note: !p<.10,**p<.01, ***p<.001

In table 12 student scores for both A and B schools were significantly higher ($p<.01$) after implementation. Student scores for school A were significantly lower ($p<.001$) than that of the control before and after implementation. School A did not improve relative to the control school.

Table 12

Difference-in-Difference Results for Science Score 5-N versus Control School

	B	SE
Intercept	150.16923***	1.4447
post	6.30299**	1.99283
treat	-6.00428***	1.66927
post*treat	-2.93186	2.46359

Note: **p<.01, ***p<.001

In table 13, student scores for both A and B schools were significantly higher ($p<.01$) after implementation. Student scores for school A were significantly lower ($p<.001$) than that of the control before and after implementation. School A did not improve relative to the control school.

Table 13

Difference-in-Difference Results for Science Score 5-P versus Control School

	B	SE
Intercept	150.16923***	1.40543
post	6.30299**	1.93866
treat	-7.02289***	1.88174
post*treat	-1.51316	2.83828

Note: **p<.01, ***p<.001

In table 14, student scores for both A and B schools were significantly higher ($p<.01$) after implementation. The student scores for school A were significantly lower ($p<.05$) than that of the control before and after implementation. The control school had a significant improvement ($p<.01$) over that of school A post implementation.

Table 14

Difference-in-Difference Results for Science Score 5-R versus Control School

	B	SE
Intercept	150.16923***	1.36729
post	6.30299**	1.88605
treat	-4.33139*	1.87392
post*treat	-7.41166**	2.78045

Note: *p<.05, **p<.01, ***p<.001

Lastly, in table 15, student scores for both A and B schools were significantly higher ($p<.01$) after implementation. The student scores for school A were significantly lower ($p<.001$) than that of the control before and after implementation. School A did not improve relative to the control school.

Table 15

Difference-in-Difference Results for Science Score 5-U Control School

	B	SE
Intercept	150.16923***	1.54223
post	6.30299**	2.12737
treat	-5.6405***	1.61263
post*treat	0.58442	2.28647

Note: **p<.01, ***p<.001

Post is binary variable which equals 1 if the student's test score was measured after the treatment school implemented science fair (regardless of whether they attended a Treatment school or a Control school) and 0 otherwise. The post variable was estimated to have a significant, positive association with test outcomes for six of the eight school pairs ($p<.01$). For student in control schools this would represent improved student achievement over time. Treatment is a binary variable which equals 1 if the student attended a treatment school (regardless of whether their test score was measured prior to or following science fair implementation) and 0 if they attended a control school. Seven of the eight treatment schools had student scores significantly lower than that of the student scores at the control school. Post*treat is an interaction between post and treat variables. If the B-value associated with post*treat is positive and significant, this indicates that the Treatment school improved relative to the control school in student test scores during the period of implementation. Only one school had a significant influence from the implementation of science and engineering fair and the influence was negative.

Of the sample of schools, three schools with 100% economically disadvantaged and five schools with less than 5% economically disadvantaged. Results show that this has no influence as a contributing factor with respect to SEF influence on standardized assessments. In the only significant regression results for school 5-R Table 14. The control school (99% economically disadvantaged) significantly outperformed a treatment school (3.4% economically disadvantaged).

To summarize the quantitative analysis, each school scores were compared pre- and post- science and engineering fair implementation. Each treatment school was then compared to only one control school due to demographic restrictions. Lastly, the chance

of an interaction between variables was analyzed. No interaction between variables existed which indicates that the explanatory variable (test scores) has the same variability across all levels. Each school showed growth from pre- to post- scores. All treatment schools scored lower when compared to the control school, indicating that schools who participated in science and engineering fair scored lower than the school that did not participate in science and engineering fair. This contradicts the results of the qualitative study, where ESEFTs indicated that participation in SEF increased academic aptitude.

CHAPTER V

DISCUSSION AND CONCLUSION

The purpose of this research was to explore the teaching strategies of exemplary science and engineering fair teachers (ESEFTs) as they integrate SEF into the science curricula. Additionally, this research explored the potential influence of science and engineering fair participation on fifth grade MST2 and eighth grade MST2 state exams.

Summary of Qualitative Findings

In this study, several themes emerged that are supported by the modern expectancy-value theory and relate to previous research. First, teachers who provide engaging activities for students increase the intrinsic value of the tasks implemented in these activities. As Bellipani and Lilly (1998) suggested, students who are successful in science, understand the value of what they are learning. This is supported by the modern expectancy-value theory where individuals who internalize or personalize value are expected to gain valuable knowledge from the tasks they perform (Eccles & Wigfield, 2002).

Additionally, inquiry activities, such as science and engineering fair projects or competitions, provide an intrinsic value for those activities that can often lead to future career plans for students. This is in agreement with research (DeClue et al., 2000; Tillman, 2011) that indicates teachers who value science inquiry activities, such as science and engineering fair projects, produce students with a greater understanding of

how to “do” science. The students become vested in the intrinsic value of science inquiry and believe that utilizing engaging opportunities such as science and engineering fair project have the potential to provide valuable experiences needed in their future careers and students often choose careers in the STEM fields (Sahin, 2011).

Also, the development of intrinsic value for science inquiry and science and engineering fair is supported by engaging activities that increase motivation and lead toward increases in academic success. Eccles and Wigfield (2002) in the Modern Expectancy-Value Theory suggested that the overlap of intrinsic value, motivation and academic aptitude is quite common. An additional study (Dionne et al., 2012) also indicates that teachers who have an intrinsic value for science and engineering fair, promote the science and engineering fair in a positive way. Then quite often this develops into intrinsic value within the student, who is then motivated to conduct research. In the process of conducting the research, the student develops skills and abilities that often overlap in to other content courses. Mr. Anderson indicated that he has witnessed this pattern “lead to an increase in grades in other classes”. Therefore, the potential exists for intrinsic motivation in science and engineering fair to lead to an increase in academic aptitude not only in science, but other content as well. This open support of science inquiry, motivating students to achieve in science, as indicated by Feng and McComas (2015), could lead to high science achievement.

Although the cost of engaging students in science inquiry activities can vary in money, time, support and negative perception of the ill-informed, the benefits far outweigh those costs.

Within the data analysis, and emphasis of the importance of responsibility and its relationship with utility value emerged. As mentioned earlier, this could provide evidence for an intertwined relationship among utility value, motivational value and the intrinsic value of responsibility for the individual in science education. Research by Eccles and Wigfield (2002) and Heckhausen (1991) both indicated that the expectancy-value model has the potential for multiple overlaps, such as the one described in this research. This particular overlap described could be a potential area for research in future studies.

ESEFTs Suggested Teaching Strategies That Support Success in SEF

The qualitative study also paints a picture of ideal teaching methodologies through inquiry-based learning activities and laboratories as well as the beliefs of all ESEFTs that support is essential for science and engineering fair as an authentic assessment of the nature of science as suggested by several researchers (Bellapani & Lilly, 1999; Lederman, 1998; McComas, 2011). Through the desire to implement SEF into the curriculum of their classroom, this set of 6 ESEFTs have provided 9 essential guidelines, or a teacher's toolbox, for overall success with SEF and the potential impact on student learning.

First, ESEFTs feel that it is important not to stress the competitiveness portion of the science and engineering process. This finding is supported by current research (Czerniak & Lumpe, 2006), where low-achieving students perceived negative connotations when mandated to compete in science and engineering fair. However, if competition was not mandated, the students improved in self-efficacy of science. Therefore, if science and engineering fair where incorporated into the science curriculum as an effective teaching tool (Ndlovu, 2013), students could potentially increase their

self-efficacy of science (Finnerty, 2013), understanding of NOS (McComas, 2011), and potentially choose STEM careers (Sahin, 2011).

Secondly, when describing the most important aspect of a high quality SEF project, all ESEFTs were in agreement that greatest aspect of a high quality SEF project was how the student "told the story" through the way the student framed the data and justified or explained the data. Although research exists on the importance of how data is explained (Giere, 1999), no specific research was discovered on this specific insight into a high quality SEF project. However, the NRC (2012) stressed the importance of using data to tell the story "because raw data as such have little meaning, a major practice of scientists is to organize and interpret data through tabulating, graphing or statistical analysis" (p. 61). Furthermore, research conducted by Davidson (2014) indicates that the understanding of the implication of their data and expansion to include statistical analysis can add to the validity of a student's research. Therefore, data and the frame in which the student explains the data could be perceived as the most validating factor of a student's research. Teachers who include collection of data, data analysis and justification or implication of data findings in their science curriculum should adequately prepare students for high quality SEF projects.

Thirdly, all ESEFTs describes applicability as the cornerstone of a choosing a SEF project. Dionne, et al. (2012), indicated that teachers who influence students to choose SEF that will impact themselves or their community directly, increase motivational factors for participation in SEF projects. This increases the viability of the research with potential impacts on science in the community. As Eccles and Wigfield (2002) explain in the Modern Expectancy-Value Theory, increase in intrinsic value, leads

to increase in motivation, which leads to increase in utility value. This in turn could lead to a student choosing a career in a STEM field (Sahin, 2011).

Fourth, incorporation of inquiry activities and laboratories that provide practice and practical application science process skill are an essential part of the science curriculum. These teaching strategies provide the basis for student understanding of the NOS and the ability to conduct meaningful authentic research. In literature by McComas (2011) one of the themes from *A Framework for K-12 Science Education* (NRC, 2011), includes that the science education community "supports the goal that students have opportunities to experience authentic inquiry themselves" (p. 35). This coincides with the NSES that support the teaching of science inquiry in the classroom. Therefore, the combination of science process skills and science inquiry through teaching methodologies such as inquiry activities and laboratories, culminating with the SEF project, could provide an authentic assessment of the NOS (LaBanca, 2008; Lederman, 1998; McComas, 2011).

Additionally, student science achievement scores from the Program for International Student Assessment (PISA) data and student science attitudes, Feng and McComas (2015) noted that "the complexity of the impact of inquiry teaching is directly affected…by the openness of the teacher" (p.18). Feng and McComas also recognize that high quality didactic instruction is often necessary, but the incorporation of high quality science inquiry where students select their own topics and design their own investigations should be used in the correct context and within the realms of the student's capabilities. Therefore, when considering incorporation of inquiry activities and laboratories that

promote essential science process skills and the NOS, a teacher must consider the overall goal of achieving NOS within the frame of the abilities of their students.

While research conducted by Kirschner, Sweller, and Clark (2006) described the incorporation of projects like science and engineering fair projects as not necessary and even suggested that the use of science inquiry in the classroom is not needed, this notion is highly debated as incorrect by most science education researchers. The inclusion of science inquiry in the NOS (Lederman, 1999) as an effective teaching tool, the support of science inquiry by AAAS, NSTA, and the NRC, and the latest move to include inquiry within NGSS, all suggest to the importance of the inclusion of science inquiry as a successful teaching strategy. However, research by Feng and McComas (2015) suggested that although it has been established that science inquiry is an effective teaching strategy for high level teaching practices, the "proper level of inquiry should be applied with knowledge of the strengths and limitations for each level" (p. 21). They further suggested that teachers who practice teaching strategies that include high level inquiry teaching where students are developing research ideas, experimenting, and drawing conclusions, such as those involved in science and engineering fair projects, the greater the level of academic understanding and "gain of insights about science" (p. 21).

The fifth ideal teaching strategy supporting inclusion of SEF in the classroom is the focus of identified science process skills in the classroom: specifically, prediction, communication, collecting and organizing data, and analysis or description of the impact of the data. According to McComas (2011) and Lederman (1998), the inclusion of science process skills and science inquiry is an essential portion of understanding the NOS. Additionally, Savary (2015) indicated that students who possess an understanding

of science process skills, possess the skills necessary to engage in scientific processes that involve critical thinking. Therefore, ESEFTs seem to focus on particular science processes more than others. This could be an area for further research.

The sixth ideal teaching strategy is the inclusion of SEF as a part of the science curriculum. All ESEFTs agreed that SEF can be incorporated into the inquiry strand of the science curriculum. However, several ESEFTs could not implement all of SEF in the classroom. These teachers developed other strategies such as after school programs or research programs to alleviate the classroom pressure of incorporation of SEF. The research of Field (2014), Bellapani and Lilly (1999), and McComas (2011) all indicate that inclusion of SEF projects into classroom curriculum can often be challenging. However, Field (2014) suggests that this is essential in developing key components of NOS through the framework of the SEF.

ESEFTs identify support from administration as the seventh most important aspect of support for SEF in the classroom. This relates to the value of the cost of SEF projects. Administration must be persuaded that by student participation in STEM projects such as SEF, the students could receive a greater learning experience that will translate into to potential academic success. Therefore, the benefits must outweigh the costs. The ESEFTS indicate that costs of time, money, appearance to the public and more can often be a determining factor in the administrative support. In a study by Vinkovic and Potocnik (2010), the support by administration for SEF not only created a climate of students choosing STEM careers, it also had the potential to boost the economy of urban areas with more potential workers in the technologically advanced country. Although Bellapani and Lilly (1999) and Weber (2015) indicate that cost is a large deterrent for

SEF in rural areas, partnerships between administration, community members and parents often strengthen the support for SEF.

Therefore, the eighth belief designated by ESEFTs as essential for the successful incorporation of SEF in the classroom is to make connections with local universities, extension agencies, and community members to provide mentor resources for students. Field (2002) suggests that evidence exists that professional scientists that invest in the mentoring of students in research-based activities promote success for students, support for teachers, and an increase in the quality of SEF projects as well as other student based research projects. Therefore, it is imperative that mentorships are established to facilitate classroom and research classes that incorporate SEF in the classroom.

The ninth teaching strategy involved the necessity of research courses or after school programs that solely focus on the development of research-based high school science programs such as SEF. In a similar studies on the effect of research-based high school science programs on undergraduate students, Field (2002) and Sahin (2011) indicated that students who were fortunate enough to be mentored by research scientists or other community scientists during their high school years were more likely to pursue STEM degrees with a 68% matriculation rate (Sahin, 2011). Therefore, establishing community partnerships cannot only increase the quality of a student's SEF project, it can also prepare them for future careers in STEM areas. However, in many areas, mentoring relationships could be difficult to establish without the availability of community resources, such as industry, colleges and universities.

Impact of Quantitative Research

This research indicated that overall or cumulative standardized test scores do not accurately assess student achievement in the area of inquiry or more specifically science inquiry. It is likely that because there are such few items that focus on inquiry, student growth in this area is not reflected in overall scores. Because of this lack of focus on inquiry, teachers discount the value of inquiry as an instructional tool or teaching strategy and instead focus on teaching content as opposed to science process skills or application of those skills. As we found in the literature review, quality of experience in science education includes the development or science process skills through the premise of the importance of the understanding of nature of science. Implementing science fair into kindergarten through 12 grade curricula has the potential to achieve the goals of Next Generation Science Standards. However, this will not be reflected on standardized assessments. This research suggests that these standardized assessments are flawed in their representation of science inquiry and do not represent the ideal student experience in science education. Teaching to the test results in students not understanding processes of science and thus not having an authentic experience of how science works impacting their interest in pursuing science as a career or course of study in future educational opportunities.

Although in this research we controlled for the variable of high and low economically disadvantaged, the results indicated that the high economically disadvantaged out-performed the low economically disadvantaged. This is contrary to established research (Vincovik & Potocnik, 2010; Weber, 2010). This would suggest that

the frame of economically disadvantaged was not measured accurately in this analysis or additional research must be conducted to justify this outcome.

Lastly, in an ad hoc review of the MST2 standardized test for Mississippi, 7 out of 70 questions identified as a measurement of inquiry were identified to be at the depth of knowledge (DOK) level of DOK 1-2. The process of conducting a science and engineering fair project is DOK 4-5 and beyond. This suggests that the current standardized test structure for measurement of inquiry questions does not adequately assess science inquiry. This could potentially explain why the use of the MST2 as a measure of science inquiry in this study was not an adequate measure of a student's science inquiry ability.

Limitations of the study

There are several implications for the validity of this research. The perspective or point of view of the quantitative portion of this research was from the viewpoint of the ESEFT. The researchers asked the teachers to not only interpret their views but their student's views as well. Future research could include additional exploration of the perspective from the student's point of view. Additionally, teachers could also be concerned with how they will be perceived by the researcher due to the position of the researcher as a regional, state, and international chair or committee member. Every effort was made to assure the ESEFTs that their comments would have no benefit or deterrent to participation or treatment of their students in any of the aforementioned competitions.

Additionally, the quantitative portion of this research was limited by archived data. It was not possible to obtain only the science inquiry data from the state tests. Therefore, a methodology that would include a strategic intervention by the researcher

with an instrument of measurement of specifically science inquiry in the frame of a pre and post strategic intervention could provide additional insight and validity to the study. For example, local schools that have not been involved with science and engineering fairs could receive training for the teachers and assist the schools with implementation of the SEF with pre and post science inquiry assessment instrument. This could be addressed through further research within this frame of reference.

Future Direction of Research

The overall outcomes of this study outline successful teaching strategies implemented by exemplary science and engineering fair teachers to promote NOS through the frame of science and engineering fair projects through student vested development and presentation at the international level. It is the hope of this researcher that teachers who would like to successfully incorporate higher level inquiry learning in the science classroom could use the tools identified in the *teacher's toolbox*, to include or strengthen science inquiry in the classroom through justification of science and engineering fair as an authentic assessment of science inquiry in correlation with current science curricula.

While analyzing the research, another theme emerged that was not explored further, rural implications. Rural school implications seem to indicate a huge cost expectancy that was not explored in this research, such as lack of funding for inquiry activities, doing without supplies, lack of quality teachers, having to teach multiple "preps" or courses, etc. The teachers seemed to suggest that rural issues affect academic aptitude, self-efficacy, self-worth, and self-regulation. All of these affects could be separate studies in their own right.

An additional outcome of this research indicates that standardized tests used to measure the aptitude of science do not adequately measure the growth in science inquiry. Therefore, it is the recommendation of this researcher that the development and implementation and experiential learning project that included science and engineering research project over a succession of years, evolving into a science portfolio, could provide an authentic assessment of science inquiry for a student. Future research in this area could include a professional development that trained teachers on the teaching strategies included in a *teacher's toolbox*, a defined authentic assessment outline and/or rubric for measuring the growth in science inquiry, and collaboration between the teachers involved in the professional development to assess the validity of SEF as an authentic assessment of science inquiry.

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APPENDIX A

DEMOGRAPHICS

Please complete the following demographic information.

- Participant Code_____
- Gender_____
- Age_____
- Years of Teaching Experience_____
- Grade Currently Teaching_____
- Subject Currently Teaching_____
- What percent of your students participate in science fair_____
- How many ISEF Finalists/Alternates have you had?_____
- Do you currently teach at a title I school?_____
- How would you classify your school? (Rural, Urban, City)
- What is the socioeconomic status of the majority of your students? (Low, Middle, High) Describe.

APPENDIX B

LETTER TO PARTICIPANTS/CONSENT FORM/IRB APPROVAL EMAIL

Hello Key Science Fair Teachers:

I, Christina McDaniel, a Ph.D. candidate in the College of Education, Department of Curriculum, Instruction, and Special Education, along with Dr. Ryan Walker, Assistant Professor in Secondary Science Education at Mississippi State University, would like to invite you to participate in a research study entitled "A Mixed Methods Study of the Relationships Among Academic Performance, Science Fair Participation Level, and Teaching Methodologies". The focus of this research is to identify teaching strategies of exemplary science fair teachers.

You have been identified as an exemplary science fair teacher and selected to participate in this study to identify unique teaching practices of teachers who have had students compete/participate in the Intel International Science and Engineering Fair. Participation in this study consists of several phases: (1) a 50-60 minute audio-recorded interview, (2) biweekly email journal, (3) one classroom observation, (4) summative interview, (5) and potential follow-up interviews. The initial interview will consist of questions related to science inquiry in the classroom, teaching strategies involved in the inquiry process, and the incorporation or alignment of science and engineering fair to current science curriculum. Throughout each of the phases, you may be asked to provide supporting documents, such as lesson plans, worksheets, checklists, etc.

Please understand that participation in this study is voluntary. If you should refuse or terminate your participation in this study, there will be no penalty or loss of benefits to which you are otherwise entitled. Additionally, all personally identifiable information will be kept confidential by the researcher.

If you have any questions regarding this study, you may contact the researchers, Christina McDaniel at cm1064@msstate.edu or Dr. Ryan Walker at RWalker@colled.msstate.edu, or the Office of Research Compliance at 662-325-3294.

If you agree to participate in this study, please sign the consent form provided.

Best Regards,

Christina McDaniel, Ph.D Candidate
Department of Curriculum, Instruction and Special Education
Mississippi State University

Mississippi State University
Informed Consent Form for Participation in Research

Title of Research Study: A Study of the Relationships Among Academic Performance, Science Fair Participation Level, and Teaching Methodologies

Researchers: Christina McDaniel, Ph.D Candidate & Dr. Ryan Walker, Mississippi State University

Procedures: According to the public records of the Mississippi Science and Engineering Fairs, you have mentored 3 or more international science and engineering fair finalists in the past ten years. Therefore, you have been identified as an exemplary science and engineering fair teacher (ESEFT), and qualify for participation in this study. Participation in this study consists of several phases: (1) a 50-60 minute audio-recorded interview, (2) biweekly email journal, (3) one classroom observation, (4) summative interview, (5) and a follow-up interview. The duration of this study is approximately one month. The research focus consists of questions related to science process skills and science inquiry, teaching strategies, and science and engineering fair. Throughout each of the phases, you may be asked to voluntarily provide supporting documents, such as lesson plans, worksheets, checklists, etc.

Questions
If you have any questions regarding this study, you may contact the researchers, Christina McDaniel at cm1064@msstate.edu or Dr. Ryan Walker at RWalker@colled.msstate.edu, or the Office of Research Compliance at 662-325-3294.

Voluntary Participation

Please understand that your **participation is voluntary.** Your **refusal to participate will involve no penalty or loss** of benefits to which you are otherwise entitled. You **may discontinue your participation** at any time without penalty or loss of benefits.

Use this section if signed consent will be obtained.

Please take all the time you need to read through this document and decide whether you would like to participate in this research study.
If you agree to participate in this research study, please sign below. You will be given a copy of this form for your records.

_____ _____

Participant Signature Date

_____ _____

Investigator Signature Date

From: nrs54@msstate.edu
Sent: Tuesday, September 06, 2016 4:29 PM
To: McDaniel, Christina; Brenner, Devon; Ivy, Jessica; Clary, Renee; Walker, Ryan
Subject: IRB Protocol Approved: IRB-16-347, McDaniel, Christina

IRB has approved the protocol with the following details.

Protocol ID: IRB-16-347
Principal Investigator: McDaniel, Christina
Department: Dean of Education
Protocol Title: A Study of the Relationships Among Academic Achievement, Teaching Strategies, and Science and Engineering Fair Participation
Review Type: EXEMPT
Approval Date: September 06, 2016

APPENDIX C

EMAIL TRANSCRIPT

Hello Key Science Fair Teachers:

I, Christina McDaniel, a Ph.D. candidate in the College of Education, Department of Curriculum, Instruction, and Special Education, along with Dr. Ryan Walker, Assistant Professor in Secondary Science Education at Mississippi State University, would like to invite you to participate in a research study entitled "A Mixed Methods Study of the Relationships Among Academic Performance, Science Fair Participation Level, and Teaching Methodologies". The focus of this research is to identify teaching strategies of exemplary science fair teachers.

You have been identified as an exemplary science fair teacher and selected to participate in this study to identify unique teaching practices of teachers who have had students compete/participate in the Intel International Science and Engineering Fair. Participation in this study consists of several phases: (1) a 50-60 minute audio-recorded interview, (2) biweekly email journal for approximately one month, (3) one classroom observation, (4) summative interview, (5) and potential follow-up interviews. The initial interview will consist of questions related to science inquiry in the classroom, teaching strategies involved in the inquiry process, and the incorporation or alignment of science and engineering fair to current science curriculum. Throughout each of the phases, you may be asked to provide supporting documents, such as lesson plans, worksheets, checklists, etc.

Please understand that participation in this study is voluntary. If you should refuse or terminate your participation in this study, there will be no penalty or loss of benefits to which you are otherwise entitled. Additionally, all personally identifiable information will be kept confidential by the researcher.

If you have any questions regarding this study, you may contact the researchers, Christina McDaniel at cm1064@msstate.edu or Dr. Ryan Walker at RWalker@colled.msstate.edu, or the Office of Research Compliance at 662-325-3294.

If you agree to participate in this study, please email me back as soon as possible to schedule a time to interview and observe.

Best Regards,

Christina McDaniel

APPENDIX D

INTERVIEW PROTOCOL

Introductory Paragraph

First, I would like to thank you for agreeing to participate in this research. Once again, I am Christina McDaniel, the science and engineering fair director at Mississippi State University, secondary science education instructor/undergraduate academic advisor, as well as a Ph.D. candidate in Curriculum, Instruction and Special Education at Mississippi State University. I am conducting research relating to the value of science engineering fair participation in preparing students for academic achievement and future careers in the growing technologically global world. Specifically, I am interested in teaching methods that promote success in science and engineering fairs. Please understand that participation in this research is voluntary. Your refusal to participate in the research process will involve no penalty or loss of benefits. By agreeing to participate in this research, you are agreeing to an interview, a follow up observation and provision of supporting documents related to this research. If at any time during the research process, you would like to discontinue participation in a portion or all of the research process, please feel free to communicate this to the researcher immediately. If you agree to participate in this research, please sign this consent form (hand consent form to participant).

Interview Questions

1. How would you define an exemplary science and engineering fair teacher?
    - What is the difference between an exemplary science and engineering fair teacher and an exemplary science teacher?
    - What are some similarities between both?
2. Describe your personal experiences with Science and Engineering Fair?
    - Successes
    - Failures
    - Examples

3. In your opinion, what constitutes a high quality science and engineering fair project? Can you show me an example of a de-identified high quality science and engineering fair project from a previous year? Why is this high quality?

4. How do you introduce and incorporate science and engineering fair projects into the classroom? For example, is there a specific sequence of events, activities, presentations, etc. that are used to introduce the SEF?
    - Specific activities
    - Labs
    - Worksheets
    - Group work
    - Presentations
    - Videos
    - Others

5. Do you feel student participation in science and engineering fair has an impact on academic performance of all of your students who participate in science and engineering fair?

- Does participation in science and engineering fair impact more than academics? If so, elaborate.
  - Career
  - Nature of science

  If not, elaborate.
- Is SEF just for those who are scientifically inclined? Why or why not?
- How do you feel participation in science and engineering fair aligns with the inquiry strand of the Mississippi Science Standards? Be specific.

6. Describe the support/recruitment of science fair by:

- Students
- Other Teachers
- Administrators
- Parents
- Community
- Science Fair state and national staff???
- Websites?
- Etc.

Have you ever encountered opposition to SEF? Explain. How did you handle it?

7. You have had a number of SEF finalists. What do you think makes you so successful?

8. How is the time you are spending preparing for science fair the same as or different from the rest of your science curriculum? Why? Elaborate.

9. Are you familiar with the terminology, "science process skills"? If no, give definition……If yes, ask…How would you define science process skills? Can you give me some specific examples of how you use process skill in your classroom? (As the participant is explaining specific activities or science process skills used in their classroom, check of each specific science process skill from the list below. Ask for specific examples or elaborations as needed. Ask for examples and artifacts to support the specific activities.)

- Observing
- Measuring
- Inferring
- Classifying
- Predicting
- Communicating

- Formulating hypothesis
- Identifying and defining variables
- Describing relationships between variables
- Designing investigations
- Experimenting
- Acquiring data
- Organizing data in tables and graphs
- Analyzing investigations and their data
- Understanding cause and effect relationships
- Formulating models

10. How would you describe or define science inquiry? Are there different levels to science inquiry? Describe how the levels of science inquiry are different? How do you progress in levels of inquiry within your lessons?

11. Does your school environment impact the incorporation of science inquiry in the classroom? If so, elaborate

- Funding
- Administrative support
- Physical space
- Curriculum requirements
- Other

What other are the challenges of incorporating science inquiry in the classroom? Can you provide examples?

12. Describe an inquiry activity that has proved to be very successful in your classroom. Why do you think it is so successful? (Collect artifacts to support this lesson.)

Describe a type of inquiry that was not so successful. Did you try to improve the activity? How? Was it successful?

13. What are some specific changes to the current science curricula that affect how science inquiry is incorporated in the classroom? Describe how it has effected your classroom directly. Can you provide examples?

- Local/District Level
- State Level
- National Level

14. In the state of Mississippi, a student's aptitude for science inquiry is measured on the MST2 in fifth grade, eighth grade and Biology SATP2.

- What is your experience with these exams?
- How do they assess inquiry?
- How do you prepare your students for the inquiry portion of these exams?

- What kind of resources are provided for preparing students for these exams?
- How well do you feel these exams measure science inquiry? Why do you think that? Evidence?
- What evidence do you have that you in particular are preparing your students for the inquiry portion of these exams?

15. Are you aware of any current legislation or educational reforms that encourage or highlight science inquiry?

- If education legislation were to mandate the incorporation of science fair or an alternate STEM program in to the curriculum for every science course K-12 would you be in support of the legislation?
- Why or Why not? Be descriptive.

16. We have discussed science inquiry and science process skills at length. What do you think inquiry and process have to do with science and engineering fair? Elaborate.

17. Is there anything else you would like to add in relation to science and engineering fair, science inquiry, science process skills, or other related topics.

APPENDIX E

DATA TALLY SHEET

Participant _____ Location_____

	Descriptive Notes			
	Initial Interview	**Biweekly emails**	**Observation**	**Summative Interview**
Observing				
Measuring				
Inferring				
Classifying				
Predicting				
Communicating				
Formulating Hypothesis				
Identifying and defining variables				

Designing investigations				
Experimenting				
Acquiring data				
Organizing data in tables and graphs				
Analyzing investigations and their data				
Understanding cause and effect relationships				
Formulating Models				
Types of Inquiry				
Confirmation				

Structured				
Guided				
Open				

APPENDIX F

BIWEEKLY JOURNAL EMAIL PROMPT

Dear (Insert Participant Name),

This is a reminder to complete your biweekly journal for the study titled, **"**A Mixed Methods Study of the Relationships Among Academic Performance, Science Fair Participation Level, and Teaching Methodologies". Each time your send a journal entry, include the following:

1. Write 2-4 paragraphs to describe what you have done over the last few days, why, and how it went.

2. What are you planning to do next and why?

3. Attach any teaching resources, lesson plans, directions, etc. to support your responses.

Based on your responses, I might send a follow up email, if clarification is needed.

Again, I would like to thank you for your willingness to participate in this study.

Best Regards,

Christina McDaniel
Ph.D. Candidate, Mississippi State University

APPENDIX G

EXAMPLE OF CHECKLIST OF DATA COLLECTION AND ARTIFACTS

	Description			
	Lesson Plans	Worksheets	Checklists	Inquiry Activities
Participant 1				
Participant 2				
Participant 3				
Participant 4				
Participant 5				
Participant 6				
Participant 7				
Participant 8				
Participant 9				
Participant 10				

APPENDIX H

SCIENCE CLASSROOM OBSERVATION RUBRIC

	Not Evident				Exemplary
Classroom Culture is Conducive to Learning Science					
Ideas, questions, and contributions are exchanged respectfully.					
• Teachers interacts respectfully with students.	0	1	2	3	4
• Students interact collegially.	0	1	2	3	4
• Students and teachers jointly decide what science related idea will be discussed or investigated.	0	1	2	3	4
• Students listen actively and ask for clarification when they don't understand.	0	1	2	3	4
Discussions are based on scientific evidence. Teacher encourages students to:					
• use supporting and refuting evidence to inform reflection and discourse.	0	1	2	3	4
• rely on their own thinking and logical arguments to evaluate ideas.	0	1	2	3	4
• explain, question, and debate their own understanding.	0	1	2	3	4
• use observation and evidence to challenge ideas and inferences.	0	1	2	3	4
• differentiate between personal and scientific ways of knowing.	0	1	2	3	4
Science content is made accessible to each student.					
• Content and instruction is adjusted based on the background knowledge and skills of each student.	0	1	2	3	4
• Explanations and clarifications are clear, accurate, and accessible to each student.	0	1	2	3	4
• Spoken and unspoken messages communicate that each student is capable of learning science.	0	1	2	3	4
• Teacher encourages each student to actively participate in thinking and learning.	0	1	2	3	4
• Teacher encourages each student to experience scientifically productive disequilibrium.	0	1	2	3	4
Science Content is Intellectually Engaging					
Science content is significant, accurate and worthwhile.					
• Science content is explicit and apparent to students.	0	1	2	3	4
• Science content is primarily focused on big ideas supported by relevant concepts, facts and terms.	0	1	2	3	4
• Science content is within the bounds of an agreed upon body of knowledge.	0	1	2	3	4
• Science content is accurate.	0	1	2	3	4
• Science content is developmentally appropriate and scaffolded appropriately.	0	1	2	3	4
• Science is portrayed as a dynamic body of knowledge that changes based on the best available evidence.	0	1	2	3	4
Science content builds on students' prior ideas or experiences. Teachers encourage students to:					
• Reveal their preconceptions about the science content, the underlying related concepts	0	1	2	3	4

• Reveal their underlying thinking and reasoning and the source of their preconceptions.	0	1	2	3	4
• Recognize links between their preconceptions or previously learned science concepts and the activities or experiences in the science lesson.	0	1	2	3	4
Science content is intentionally connected to the classroom activities and experiences.					
• Actions and interactions focus on understanding important and relevant science content.	0	1	2	3	4
• Generate and explore questions about the science lesson.	0	1	2	3	4
• Articulate the intended science content of a lesson activity or experience.	0	1	2	3	4
Instruction Fosters and Monitors Student Understanding					
Instruction fosters students' emerging understanding of science content.					
• Students are confronted with evidence that challenges their initial ideas as opportunities for productive disequilibrium.	0	1	2	3	4
• Questions enhance the development of students' understanding of key conceptions connected to the lesson.	0	1	2	3	4
• Clear and accurate explanation/clarification are provided at appropriate points.	0	1	2	3	4
• Opportunities are provided for students to build on their present understanding as they develop new understandings.	0	1	2	3	4
• Student generated questions are pursued based on their relevance to the science content and their potential to deepen student understanding.	0	1	2	3	4
Instruction monitors students' emerging understanding of science content.					
• Student ideas are recognized, even when they are vaguely articulated.	0	1	2	3	4
• Responses to student questions or comments address the scientific idea expressed in their thinking and relate it to the focus of the lesson.	0	1	2	3	4
• Learning experiences are modified or added to ensure students develop the necessary science content knowledge.	0	1	2	3	4
Students Organize, Relate, and Apply Their Scientific Knowledge					
Students make sense of the intended scientific ideas and concepts. Teacher provides opportunity for:					
• Students to work on answering scientific questions or problems and objectively communicate their findings.	0	1	2	3	4
• Students to clarify their own ideas, observations, reasoning, models, and explanations of core science concepts.	0	1	2	3	4

• Students to self-monitor the accuracy of their understanding and revise their ideas based on scientific reasoning and evidence that led to them.	0	1	2	3	4
• Students to describe the difficulties they confronted in developing new and more accurate understanding.	0	1	2	3	4
Students reflect on their own understanding of the science content. Teacher provides opportunity for:					
• Students to engage in private think time to reflect on the content within the lesson.	0	1	2	3	4
• Students to reflect critically on their own and each other's processes, reasoning, and explanations.	0	1	2	3	4
• Students to discuss what they understand and don't understand about the intended content.	0	1	2	3	4
Students make connections between the science content in the current lesson and prior experiences in and out of school. Teacher provides opportunity for:					
• Students to articulate a purpose for the content beyond the immediate classroom lesson.	0	1	2	3	4
• Students to make multiple connections to what they already know or to applications in real world contexts.	0	1	2	3	4
• Students to apply what they learn beyond the context of the original problem.	0	1	2	3	4
• Students connect the science ideas to everyday life.	0	1	2	3	4

APPENDIX I

SUMMATIVE INTERVIEW POTENTIAL QUESTIONS

A summative interview will be conducted with each participant to clarify any additional questions or insights that arise during the data collection process. The summative interviews will include the following questions:

1. What do you think about current SEF projects?

2. What do you think constitutes a strong SEF project? May I see an example of what you consider to be a strong SEF?

2. What do you think constitutes a weak SEF project? May I see an example of what you consider to be a weak SEF?

3. What will you do differently in the future in regards to SEF?

4. What is next for science fair?

5. What unique resources have you acquired to support SEF?

6. During this study, you have been asked to comment on activities and lessons in your classroom that support SEF. What have you learned about yourself during this process?

One or two additional questions could be asked as needed for clarification of previously collected data.

APPENDIX J

DE-IDENTIFIED DATA METHODS

Personal Identifiers

All education and workforce data in the SLDS are linked by a 10-digit unique identification number (ID10) created at random using a hardware-based quantum physics true random number generator. All data in the SLDS to be reliably linked over time and across governmental entities contributing data to SLDS. All de-identification procedures are implemented with appropriate physical, technical, and administrative protections in place to maximize security, minimize risk, and ensure regulatory compliance as prescribed by the SLDS Governing Board Rules and Regulations. Therefore, all aggregate data received by researcher will contain no identifiers.

Data Quality Measures

The state data clearing house takes two steps to ensure data quality. The first step is to fully inventory data transferred to the clearinghouse. Data contributors submit data in accordance with state and federal law. Upon receipt of SLDS data, the National Strategic Planning & Analysis Research Center (NSPARC) verified the list of data elements received within ten (10) working days of receipt. Upon verification of the list of fields, tables, and relationships between tables by the data contributor, the data undergo a complete data inventory process. This process includes updating or creating data dictionaries and program data mapping documents. Data dictionaries included metadata such as meaning, relationship to other data, origin, usage and format. The second step was data validation that included, but was not limited to, the following activities: (1) Checking that all tables, records, and fields, and the full contents of each field, have been successfully transmitted and read; (2) Comparing record counts between the source data

and the data transmitted to the third party contractor; and (3) Producing a report with basic summary statistics for validation by the data contributor.

Security Measures

Security was maintained on multiple levels, including SSL encryption, user-specific data access controlled via user accounts, and access control lists (ACLs) for all data. NSPARC protects information from a variety of threats and stresses the importance of multi-layer protection. Through staff orientation, Institutional Review Board for the Protection of Human Subjects (IRB) certification, university information security certification, and regular staff meetings, each nSPARC staff member is aware of, committed to, and accountable for his or her role in the overall protection of critical and sensitive information. System security features implemented at nSPARC ensure secure access by authorized personnel only, with all reporting features in compliance with FERPA and other state and federal law. All data transferred to nSPARC for management and analyses are governed by the SLDS Governing Board and the terms and conditions set forth in MOUs executed between nSPARC and individual data contributors. Furthermore, all sensitive data for which nSPARC is the custodian are transferred via a secure web server that relies on Secure Socket Protocol combined with secure, managed file transfer software called JSCAPE. Uploaded data are encrypted using SSL/TLS with a 128-bit key. Once received, all files are automatically encrypted using an RSA 4096-bit key and moved to a secure offline location for storage. All primary identifiers (e.g., names, street addresses, telephone numbers, and identification numbers) are stripped from datasets once the ID10 has been assigned. Information security policies and procedures are continually reviewed and evolve in response to changing information

security technologies, requirements, and threats. All interactions with data will take place at nSPARC on the secure server.