THE EFFECT OF GK-12 GRADUATE FELLOW INTERACTIONS ON HIGH SCHOOL STUDENT ATTITUDES TOWARD SCIENCE AND CAREER PATH

by

Rachel Renee Lytle

Committee Members:
Dr. Kim Sadler
Dr. Anthony Farone
Dr. Michael Rutledge

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ABSTRACT

The purpose of this study was to determine the effect of biology graduate student interactions on high school student attitudes toward science and career choice. Through the National Science Foundation GK-12 program at Middle Tennessee State University, Graduate Fellows (GFs) partnered with a science teacher (PT) ten hours a week during the school year to serve as a scientist-in-residence, engage students in inquiry-based laboratory experiences, and mentor research projects. A multi-method design compared PT classes with and without a GF using the Student Attitude Inventory- II (SAI-II), interviews, and student artifacts. Although small positive differences were present in GF classes, repeated measures MANOVA found no significant differences between SAI-II categories. Both groups decreased in STEM career interest; however, student interviews with GF classes conveyed increased understanding of the scientific process and a desire to continue practicing science. Although GF classes actively participated in documented STEM experiences, this study supports the challenges in changing student attitude about science and increased pursuance of STEM careers.

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I. INTRODUCTION

Since 1999, the National Science Foundation has funded over 200 Graduate Fellows in K-12 Education (GK-12) programs in the United States and Puerto Rico ("About NSF GK-12," 2013). The purpose of GK-12 is for interactions with K-12 teachers and students to improve graduate fellow (GF) communication. Middle Tennessee State University received funding for the GK-12 program, Reforming Graduate Education by Integrating Teaching, Research, and Industry Applications to Deepen Scientific Understanding (TRIAD) in 2009. The TRIAD program created partnerships with selected biomedical and biotechnology companies, local high schools, and MTSU. One purpose of TRIAD is to integrate project-based learning through scientific research in high school biology classes to improve GF communication as well as enrich high school science content and instruction. Within the TRIAD program, graduate fellows (GFs) are placed with partner teachers (PTs) to interact with high school science students in the classroom for one year by teaching labs, developing engaging lectures, and mentoring student-led authentic research projects. The year culminates with the secondary students presenting their research at venues such as the annual meeting of Tennessee Junior Academy of Science (TJAS) or the TRIAD Research Symposium. This two year study examined the influence of the TRIAD program on the high school students; more specifically, their attitudes toward science and interest in pursuing a science career.

While there are numerous studies discussing GK-12 program findings, the majority focus on the impact of the program on the GFs (Gengarelly & Abrams, 2008; McBride, Brewer, Bricker, & Machura, 2011; Page, Wihelm, & Regens, 201l; Stamp & O'Brien, 2005; Trautmann, 2008). Some studies that found improved communication and collaboration skills in GFs did mention administering high school student attitude surveys but did not publish those findings (Page et al., 2011; Stamp & O'Brien, 2005), most likely due to the challenge that research involving GK-12 program students presents (Trautmann, 2008). Designing and carrying out a study to collect high school student data is extremely difficult because there are so many external variables to consider (teacher effect, a suitable comparison group, student assent, parent consent, sample size, etcetera.). The lack of research related to interactions with the GFs is discussed in a 2002 paper which proposes questions about how classroom students and their views about science and scientific literacy should be examined by the GK-12 programs (Thompson, Metzgar, Collins, Joeston & Shepherd, 2002). An editorial in *Science* proposed that a "GK-12 enhanced" program should involve research about K-12 student attitudes and career ambitions (Boone & Marsteller, 2011). These reasons lend support as to why we chose to focus on the classroom student and examine attitude and career aspirations.

Student Attitude Toward Science

Although the NSF GK-12 program literature is limited in regard to classroom student outcomes after interactions with a GF, other studies related to student attitudes toward science [1] have been studied internationally for over forty years (Bennett & Hogarth, 2009; Osborne, Simon, & Collins, 2003). Student attitudes are formed and solidified early during the secondary education years (Bennett & Hogarth, 2009; Simpson & Oliver, 1985). After this age, students maintain an impression of science that once formed, is long-lasting and difficult to alter (Ajzen & Fishbein, 1980; Harvey & Edwards, 1980). This is also when student attitudes toward science decline significantly (Osborne et al., 2003). Because enduring attitudes toward science are both formed and declining during this time period in a student's life, it is important that implementation of interventions occurs at this age.

Research shows that student attitudes toward science start highly positive in younger years, and over time, become more negative (George, 2006; Yager & Penick, 1986; Simpson & Oliver, 1985; Breakwell & Birdsell, 1992; Galton, Gray, & Ruddock, 2003). Yager and Penick (1986) conducted a study which examined student attitudes toward science at varying ages (9, 13, 17, and young-adult) in 1977, 1982, and 1984. The survey included statements that science classes are fun, science classes are interesting, and science classes are exciting, and the same trend emerged between the age groups for all three years. Nine-year olds responded most positively, with 13, 17, and then young-adults' attitudes steadily declining (1986). Similarly, Simpson and Oliver (1985) found 6^{th} and 7^{th} grade students to be most positive while 8^{th} and 10^{th} students harbored the least

[1] Attitudes towards science has been defined many ways. For the purposes of this study, it is defined as "the feelings, beliefs, and values held about an object which may be the enterprise of science, school science, the impact of science on society, or scientists themselves" (Osborne et al., 2003, p.6).

positive attitudes toward science. Breakwell and Birdsell (1992) found even with the influences of parents and peers removed, the trend still stood with younger students having a more positive attitude, and that attitude toward science decreased as students entered secondary school. In a more recent study, the noted decline in student attitudes toward science was found to be greater even than in other school subjects (Galton, Gray, & Ruddock, 2003).

Reasons for the decline in attitudes toward science at the secondary level are still under study. Several ideas about why this occurs are that students lack an understanding of how useful science is, students are negatively affected by the media's portrayal of science and scientists, or that students avoid science altogether because there is a perceived high likelihood of failure in scientific courses. When the hypothesis related to the utility of science was tested, students displayed an overall positive attitude about the usefulness of science, meaning they are actively aware of the benefits of a scientifically infused society and yet are still losing interest (George, 2003; George, 2006; Osborne et al., 2003). Related to media communication, a study was conducted to test the relationship between 21st century television viewing on the public's decreasing attitude toward science and found no significant relationship (Dudo et al., 2010). Lastly, multiple studies have looked into how risk of failure of academic courses plays into the decrease in scientific attitudes. For example, early secondary students have a fear of failing difficult classes (Masnick, Valenti, Cox, & Osman, 2010; Osborne et al., 2003). Students perceive science to have a higher risk of failure than arts-based courses and are more likely to focus on the lower risk option, even though it may be less profitable for their future career possibilities (Osborne et al., 2003). Students lack comfort when presented with questions they cannot answer and rather than risk getting the question wrong, they avoid academic tasks that involve that possibility (Piburn & Baker, 1993). These are all plausible explanations for the cause of the decline in student attitudes and yet much is still unknown.

Possible solutions to create a paradigm shift in student attitudes back toward the positive spectrum is an important and timely research topic. Two major foci have been on integrating mentors into the lives of students and increasing the amount of inquiry-based science lessons in secondary education; both of which are major components of the TRIAD program. Throughout educational history, mentors have been used to demonstrate tasks of a profession to students (ex. shadowing a medical professional, learning as an apprentice, completing an internship, etcetera). This is modeled in our use of GFs as mentors in the classroom for the high school science students. With fellows as mentors and often closer in age to the students than their classroom science teachers, the students could possibly relate more easily to the GFs and may even ask questions more freely. Budding experts in their fields, GFs are enthusiastic about their research and may be able to demonstrate this to the students and increase student attitudes about science (Masnick et al., 2010; Raju & Clayson, 2011). One other reason GF mentors are helpful is they have had personal experiences (successes and failures) in their fields and can share the knowledge gained from these with their students. Fellows may be able to share stories of multiple failed experiments and encourage students who fear science due to its risk to learn and grow from their experiences in science (Gengarelly & Abrams, 2008).

Science Inquiry in the Classroom

One other major focus in regard to reversing secondary student attitudes toward science is the application of inquiry in the classroom. There is substantial research related to how inquiry is a beneficial educational tool, and the focus in this study is on the effect of inquiry-based learning experiences on student attitudes toward science. When Piburn and Baker (1993) interviewed elementary, middle and high school students asking what they would change if they were the science teacher, a few common themes in the responses dealt with making science more exciting, less by the book, and more student led. Another research study by Ebenezer and Zoller (1993) verified that students preferred taking an active role in the lessons, bearing some responsibility for their own learning. Furthermore, Hofstein and Lunetta (1982) report that completing laboratories in the classroom increases student attitudes toward science. With these implications, it is recommended that science at all levels should implement more open-ended laboratories (Piburn & Baker, 1993).

More recently, other GK-12 programs across the country that have implemented inquiry into K-12 classrooms in various ways have made statements alluding to how the student attitudes toward science and science careers have been affected. In a GK-12 program in Ohio, more than half of the involved students reported an increased interest in engineering along with an increased confidence in their ability to learn math and science, taking away some of the fearful risk involved (Raju & Clayson, 2011). Teachers and fellows from other GK-12 programs claim their students expressed increased interest and a more positive attitude when inquiry was implemented through their program (Gengarelly & Abrams, 2009; Mitchell & Gillespie, 2007). Others reported their GK-12 programs impacting the future career choices of students, saying they are more interested and more likely to enter into a STEM field of work (Bruckner, 2008; Gabric et al., 2004). While all of these are encouraging statements about the impact of the mentors and inquiry-based lessons involved in GK-12 programs, the majority are based on personal statements and anecdotal findings. In comparison, the strength of this study is it utilizes a mixed-method design that includes student interviews, student artifacts, as well as pre-post survey analysis.

Science of STEM Career Choice

Reversing the negative attitudes of early secondary students toward science is imperative for many reasons. The loss of interest in science at a certain age correlates with the low number of students choosing to pursue science, technology, engineering, and mathematics (STEM) careers (Wyss & Tai, 2012). The feedback loop between interest and career choice is widely discussed in the literature and is a large concern (Masnick et al., 2010). Students that graduate from high school with high levels of preparation in science and math still may not choose a science major in college (Hossain & Robinson, 2012; Masnick et al., 2010). When surveyed, few students identified themselves as possible pursuers of the STEM field (Masnick et al., 2010), meaning they were unlikely to pursue science in college. There is also a large attrition rate of students who enter college as STEM majors and change programs before completing their degree (Hossain & Robinson, 2012). This demonstrates why the number of students graduating with bachelor's degrees in some STEM fields has declined (Hossain & Robinson, 2012; Wyss & Tai, 2012). The President's Council of Advisors on Science and Technology has noticed the lack of STEM majors graduating and in response has called for a 33% increase in STEM bachelor's degrees (PCAST, 2012). Concurrently, over the past 20 years the number of U.S. STEM jobs has grown four times faster than the total amount of employment (Hossain & Robinson, 2012). With fewer science graduates and an increased demand for STEM employees, there is a growing gap potentially endangering the scientific development of the country, and therefore, the already hindered economy (George, 2003, Hossain & Robinson, 2012; Wyss & Tai, 2012). An association between the number of STEM careers and economic performance has been found; the larger the number of scientists and engineers, the better the economy of that country (Osborne et al., 2003). Therefore, it is of the utmost importance to increase student attitudes toward science to increase the number of students choosing STEM majors and STEM careers which may then maintain the scientific standing and economy of the United States.

Purpose and Guiding Questions

The purpose of this study is to determine if introducing GFs into high school science classrooms positively influences student attitudes toward science, their interest in science research, and their interest in pursuing a STEM career. The following questions guided the study:

Q1. After interaction with a graduate fellow, what aspects of student attitudes toward science will increase?

Q2. After interaction with a graduate fellow, what aspects of student attitudes toward science will decrease?

Q3. After interaction with a graduate fellow, how did recognized student misconceptions change?

Q4. After interaction with a graduate fellow, how did student attitudes about pursuing a career as a scientist change?

Q5. After interaction with a graduate fellow, what are student perceptions about their research project experience?

II. METHODS

This study examined the effect of graduate fellow (GF) interactions with high school students in science classes of partner teachers (PT) in Middle Tennessee. Questions that guided the study included what aspects of student attitudes toward science increased and decreased, what misconceptions were addressed, how career interest changed, and what student perceptions were about their projects. The Student Attitude Inventory II (SAI-II) answered questions about student attitudes, uncovered misconceptions, and determined student career interests. Student perceptions about their research project experience were identified during GF student interviews.

Research Design

During the academic years of 2013-2014, a total of seven GFs worked with a corresponding number of PTs in six different high schools from two local school districts mentoring students via scientific research and inquiry-driven laboratories. The GFs selected were master or doctoral level graduate students with most having a research focus in cellular and molecular biosciences. Each GF was paired with one PT for the entire school year with the intended purpose from the NSF to serve as a scientist-in-residence in the classroom and improve GF communication skills as a developing scientist, rather than produce future K-12 educators. During the summer, GF and PT pairs attended the two week TRIAD Training Institute to develop a working partnership, get acquainted with the GFs research and laboratory, and plan the incorporation of authentic student-driven research into the secondary science classroom (grades 9-12). Student attitude survey materials were administered in the fall during the first two weeks of classes, prior to student interactions with the GF, and in the spring during the last month of school. Throughout the fall and spring semesters, both GFs and PTs completed online weekly journals to document classroom happenings, and GFs attended weekly meetings with the project team to discuss classroom progress on student research projects and current science education topics. GFs were required to spend at least five hours planning and ten hours in the high school classroom leading inquiry-based laboratories and assisting students with research projects.

The role of the GF in the classroom at the beginning of the year was to get to know their students by interacting with them during lessons and laboratories led by the PT. Although the GF taught lessons or laboratories throughout the year, the role of the GF as a scientist-in-residence began during the first few weeks of school. The GF did a presentation about their graduate research to better acquaint students with the GF and model the scientific process students will follow in their own projects. Throughout September and October, GFs assisted students in developing ideas and creating plans for their projects in a variety of ways: having students write down what they were interested in researching, providing them with scientific literature on various topics, discussing model organisms available to them for research, determining variables and controls, defining how they will measure these variables, listing materials and ordering information needed for projects, etcetera. GFs emphasized the importance of collecting data accurately and keeping laboratory notebooks. They assisted students in narrowing their project focus, modifying procedures, and ordering materials throughout November and December before exams and winter break. In January GFs had students set up and begin their projects; the GF aided students with troubleshooting when necessary. Data interpretation, making appropriate tables and graphs, determining what statistics to use to test for significance (depending on grade level), and ways to present research were conveyed by the GFs during February and March. During April and May, students presented their research at various venues. Overall, the role of the GF throughout the entire year was to mentor and engage students in the research process, culminating with scientific presentations.

Participants

High school student participants (GF = 199, Comparison = 117) were students in the science class of a TRIAD partner teacher (PT). The high school science classes included a variety of biological sciences courses including Biology I, Anatomy and Physiology, AP Biology, AP environmental science, and health science. The class rank of the study population consisted of 40% freshmen, 30% sophomores, 16% juniors, and 14% seniors. Demographically the study population consisted of 35% males and 65% females. When compared to the state of TN, the average demographics of the six participating schools display a close ethnic representation of TN students with a slightly higher ACT average and graduation rate (Table 1).

Table 1
Average demographic data for participating TRIAD schools

Ethnicity	Participating schools	State of TN
White	58.6%	65.6%
African American	24.3%	24.1%
Hispanic	11.1%	7.8%
Asian	5.7%	2.0%
Native American	0.4%	0.3%
Economically Disadvantaged	42.2%	58.8%
Graduation Rate	88.2%	87.2%
Average ACT Score	21.0	19.3

Instrument and Data Collection

To evaluate the effect of the TRIAD program on high school student attitudes toward science and a STEM career, a pre- and post-survey design was used. Pre-surveys were administered at the beginning of the school year before GFs began working with students, and post-surveys were completed toward the end of the school year, after students presented their research at the TRIAD Research Symposium. Classes with a fellow (GF group) were paired against a corresponding class taught by the same teacher (comparison group) to account for expected natural growth throughout the school year. The survey included a modified version of the Student Attitude Inventory-II (SAI-II, Moore & Foy, 1997) which was used to determine student attitude toward science and scientists with added demographic and career interest questions (see Appendix A). The instrument was selected because it demonstrated content and construct validity based on a judging panel and field test as well as reliability values (Cronbach's alpha reliability coefficient = .781) that fall within the acceptable range (.70 -.90). For this study a subset of the SAI-II was used and reestablishment of instrument properties in terms of Cronbach's alpha are discussed later (see results). The SAI-II is made up of positive and negative items clustered into six categories that measure similar concepts. The six categories examine (C1) ideas about theories and laws; (C2) the basis for scientific explanations; (C3) characteristics needed by an individual to conduct science; (C4) the value of scientific explanations; (C5) benefits of public understanding of science; and, (C6) personal aspirations to be a scientist (Table 2). It is scored using a five point Likert scale ranging from strongly agrees to strongly disagrees. For example, the positive item, "I would like to be a scientist," and its negative counterpart, "I do not want to be a scientist," both belong to category six about pursuing a science career.

Table 2
SAI-II categories: positive and negative attitude items

Categories	Items
C1. The laws and/or theories of science are approximations of truth and are subject to change.	
Positive	7. Scientific ideas may be changed over time. 8. Scientists are always interested in better explanation of things.
Negative	12. When scientists have a good explanation, they do not try to make it better.
C2. Observation of natural phenomena and experimentation is the basis of scientific explanation. Science is limited in that it can only answer questions about natural phenomena and sometimes it is not able to do that.	
Positive	11. Some questions cannot be answered by science.
Negative	17. Anything we need to know can be found out through science.
C3. To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one's position on the basis of sufficient evidence.	
Positive	3. Good scientists are willing to change their ideas. 16. Scientific questions are answered by observing things. 20. Scientists must report exactly what they observe.
Negative	13. Scientists should not criticize each other's work. 19. If one scientist says an idea is true, all other scientists will believe it
C4. Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects.	
Positive	30. Science tries to explain how things happen.
Negative	18. A major purpose of science is to produce new drugs and save lives. 26. Electronics are examples of the really valuable products of science. 27. A major purpose of science is to help people live better.

Table 2 continued
SAI-II categories: positive and negative attitude items

C5. Progress in science requires public support in this age of science; therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work.	
Positive	14. Most people can understand science. 15. Every citizen should understand science. 25. People must understand science because it affects their lives.
Negative	6. Scientific work is useful only to scientists. 9. Most people are unable to understand science. 24. Only highly trained scientists can understand science.
C6. Being a scientist or working in a job requiring scientific knowledge and thinking would be a very interesting and rewarding life's work. I would like to do scientific work.	
Positive	4. I would enjoy studying science. 5. I may not make great discoveries, but working in science would be fun. 10. Working in a science laboratory would be fun. 22. I would like to be a scientist. 28. I would like to work with other scientists to solve scientific problems.
Negative	21. Scientists have to study too much. 23. The search for scientific knowledge would be boring. 29. Scientists do not have enough time for their families or for fun. 31. Scientific work would be too hard for me. 32. I do not want to be a scientist.

Note. From "The scientific attitude inventory: A revision (SAI II)," by R. W. Moore and R. L. H. Foy, 1997, *Journal of Research in Science Teaching*, 34(4), p. 333-335.

Item responses were given a score of 1 to 5. The SAI-II description of the item as positive or negative determined the direction of the scale. For a positive item, a 5 corresponded to agree strongly while a 1 corresponded to disagree strongly. Negative item scores were reversed so that a 5 corresponded to disagree strongly and a 1 corresponded to agree strongly (Table 3).

Table 3
Assigned scores for student responses to SAI-II items

	Agree Strongly	Agree Mildly	Uncertain	Disagree Mildly	Disagree Strongly
Positive	5	4	3	2	1
Negative	1	2	3	4	5

Data Analysis

Student pre and post responses were matched and the differences were calculated (post-pre) for each item. If the difference was positive, that student's post-survey response reflected a more favorable attitude toward science than their pre response. For example, if on the pre-survey a student responded disagree mildly to a positive item, it was recorded as a 2. If on the post-survey the student responded agree mildly to the same item, it was recorded as a 4. The difference (post-pre) shows the student increased by 2 positive units on the scale for that attitude item (Table 4). A similar negative item calculation is also shown in Table 4.

Table 4
Calculated differences for student responses to SAI-II items

	Pre	Post	Difference
Positive			
Response Score	Disagree Mildly 2	Agree Mildly 4	4 - 2 = 2
Negative			
Response Score	Agree Strongly 1	Disagree Strongly 4	4 – 1 = 3

A difference measure was calculated for each student response to every item on the survey. Mean differences were calculated for each item, category, and overall group (GF and comparison). The General Linear Model (GLM) procedure with repeated measure Multivariate Analysis of Variance (MANOVA) in SAS® analyzed GF and comparison group difference scores for significant differences.

Interviews

In addition to survey analysis, phenomenological research via student interviews was completed to strengthen and lend further insight to the study (Ramsden, 1998). The purpose of phenomenological research is to use multiple descriptions of individual experiences with a phenomenon and combine these to describe its overall essence (Creswell, 2007). In this study, the phenomenon is the experience of interacting in the classroom and completing a research project with the mentorship of a GF. The GF students interviewed conveyed their individual views about this shared experience which assisted in understanding the impact of the TRIAD program. Criterion-based random purposeful sampling was employed to determine which students to interview. Interviewed students met the criterion of experiencing the phenomenon (working with a GF), and their random selection adds credibility due to large sample size (n=199). Following Polkinghorne's guidelines stating 5-25 interviews should be used in a phenomenology (1989), fifteen students were verbally interviewed during the 2014 TRIAD Research Symposium.

Development of the semi-structured interview questions began with questions with factual answers (name, school, etcetera), allowing the interviewee to become comfortable with talking and answering the questions (Table 5). From this point in the interview questions ranged in topic from how the student felt the GF affected their classroom to questions about their research project. Questions 16 and 17, which inquire about the difference between science and technology, were added due to interesting pre-survey results. After interview questions were completed there was an opportunity for comments from the interviewee; the purpose of this additional opportunity for comments was to validate to the interviewee that their opinion as the main focus of the conversation.

Table 5
GF student interview questions

1. What is your name?
2. Where do you go to school?
3. Who is your teacher?
4. Who is your GF?
5. What grade are you in?
6. Do you plan on attending college?
7. If so, where?
8. What major?
9. What are your plans when you are out of school?
10. What is something you learned in science this year that you think will stay with you?
11. How did things go with _______________ in your classroom?
12. How do you think science class this year would have been different without _____________ in the room?
13. What did you learn or gain from this experience?
14. Did you do a research project? What was it? Why did you pick it?
15. How many times did you mention this to family, friends, or on social media?
16. How would you explain the relationship between science and technology?
17. Some people think that science changes while others consider it more stagnant. What do you think and why?
18. Is there anything else you would like to share?

Phenomenological data analysis involved interview recording and verbatim transcription, extraction of interview statements, assemblage of common themes based on frequency, and the developed description of the overall experience (Creswell, 2007). Playing a secondary role to the interviews, student artifacts (submitted research papers, digital copies of posters, etcetera) were collected and kept as another source of data. The interview statements, themes, and descriptions were then compared to survey results for corresponding implications.

Ethics and Validity

Consent for this study was granted June 2013 through the MTSU Internal Review Board with an additional extension approved through June 2015 (Protocol #: 13-021, see Appendix B). Letters of approval from school districts and principals (on file) were obtained along with informed student assent (see Appendix A) and parent consent (see Appendix C) for both the GF and comparison groups. Only the responses of students that had given assent and turned in parent consent were used in this study.

Structural corroboration and clarification of researcher bias are employed as validation strategies in this study (Creswell, 2007). Structural corroboration, also known as triangulation, enlists multiple data forms to arrive at conclusions. In this study, those include student interviews, student artifacts, and pre-post survey analysis. To clarify researcher bias, the researcher has worked in an educational setting for 3.5 years. These years involved student teaching, a graduate teaching assistantship, a GF in the TRIAD program, and a high school teaching position. The researcher and a colleague, who also had a graduate teaching assistantship and was a GF, interviewed the students, but neither interviewed their own students. The researcher transcribed all of the interviews to ensure consistency and reflected as accurately as possible on student responses using the verbatim transcriptions.

III. RESULTS

Although small positive differences were present in GF classes, a repeated measures MANOVA found no significant differences between the treatment groups and SAI-II categories. GF student attitudes increased in C1 (about the ability of science to change), C3 (about the attributes of scientists), and C5 (about the importance of the public understanding science), and decreased in C2 (about the limitations of science) and C4 (about the relationship between science and technology Misconceptions about scientists' use of explanations remained in the GF and comparison groups. Both groups decreased in STEM career interest (C6); however, student interviews with GF classes conveyed increased understanding of the scientific process and a desire to continue practicing science.

SAI-II Categories

Pre-survey

Pre-surveys were given at the beginning of the school year to both the GF group and the comparison group before GFs started working with the students. Data was collected and converted to a 1 to 5 scale (see methods) to be matched with the post-survey results later. Descriptive statistics were calculated as well to get an overall understanding of the pre-data. Mean pre-responses display similar trends in the GF and comparison groups (Table 6). This validates the comparison group as a good fit for the study. The well-matched comparison group accounts for natural growth throughout the school year and, because each GF class has a comparison group with the same teacher, controls for the teacher variable.

Pre-responses for all students were high for most categories ranging from 3.5 to 4.3. C1 (GF = 4.3, Comparison (C) = 4.3) about the ability of science to change, and C3 (GF = 4.2, C = 4.1) about the attributes of scientists, had the highest mean scores falling in the agree range. The only category mean for pre-responses in the disagree range is C4, focused on differentiating science and technology with science as a process rather than a means to produce new technologies. Due to the disagreement in this category, an interview question was added for clarification asking GF students to describe the relationship between science and technology (Table 5).

Post-survey

Post-surveys were given at the end of the school year to both the GF group and the comparison group after students presented their research projects. Data was collected and converted to a 1 to 5 scale to calculate a difference in attitude score (post - pre). Descriptive statistics were calculated as well to get a global understanding of the post-data, which was very similar to the pre-data.

Post-mean response scores very closely reflected the pre-mean response scores for both groups (Table 6). C1 (GF = 4.4, C = 4.2) and C3 (GF = 4.3, C = 4.1) remained the highest means, in the agree range, while the C4 (GF = 2.6, C = 2.6) mean disagreement remained. Because students agreed with the positive and the negative items in C4, the means averaged out into an uncertain score, near 3.0.

Category differences were close to zero with little change in mean student responses from pre to post in both groups of students (Table 6). Frequency of differences in student responses are shown in histograms for each category (Figure 1). The category distribution trends displayed for the GF and comparison groups are alike. While no significant category gains were uncovered during analysis, no significant losses were shown.

Table 6
GF vs. comparison student response mean scores

		GF Average (n = 199)			Comparison Average (n = 117)		
Category	Items	Pre	Post	Diff	Pre	Post	Diff
C1	7. Scientific ideas may be changed over time.	4.7	4.6	-0.1	4.6	4.5	-0.1
	8. Scientists are always interested in better explanation of things.	4.2	4.3	0.1	4.2	4.3	0.1
	12. When scientists have a good explanation, they do not try to make it better.	4.1	4.1	0.0	4.1	3.9	-0.2
	Overall	4.3	4.4	0.1	4.3	4.2	-0.1
C2	11. Some questions cannot be answered by science.	3.9	3.8	-0.1	3.8	3.8	0.0
	17. Anything we need to know can be found out through science.	3.4	3.3	-0.1	3.4	3.4	0.0
	Overall	3.6	3.5	-0.1	3.6	3.6	0.0
C3	3. Good scientists are willing to change their ideas.	4.4	4.6	0.2	4.3	4.4	0.1
	13. Scientists should not criticize each other's work.	4.0	4.1	0.1	3.9	3.9	0.0
	16. Scientific questions are answered by observing things.	4.5	4.5	0.0	4.4	4.4	0.0
	19. If one scientist says an idea is true, all other scientists will believe it.	3.3	3.7	0.4	3.4	3.5	0.1
	20. Scientists must report exactly what they observe.	4.6	4.5	-0.1	4.5	4.4	-0.1
	Overall	4.2	4.3	0.1	4.1	4.1	0.0

Table 6 continued

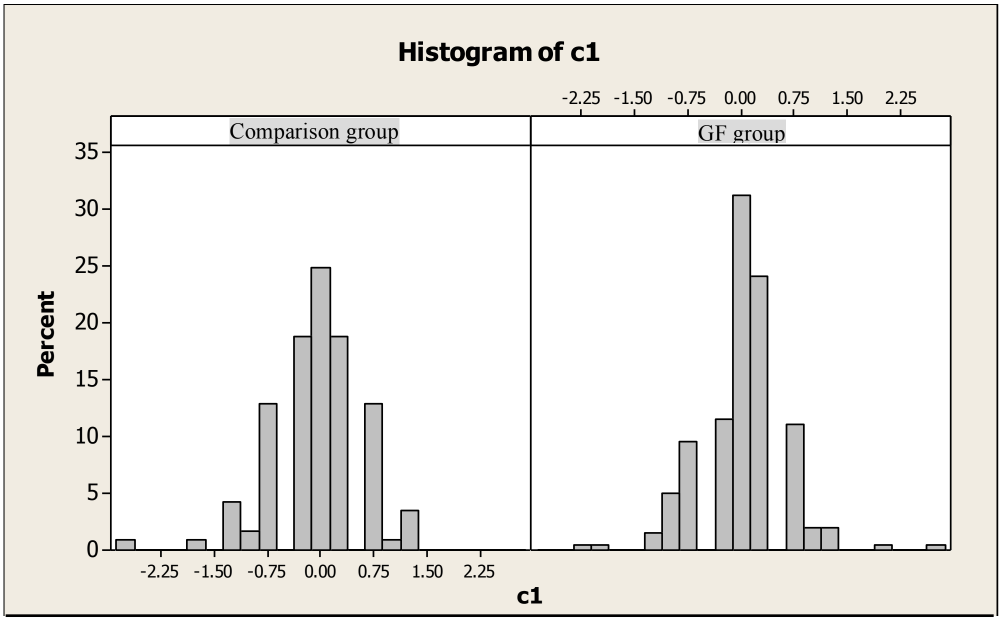
GF vs. comparison student response mean scores

		GF Average (n = 199)			Comparison Average (n = 117)		
Category	Items	Pre	Post	Diff	Pre	Post	Diff
C4	18. A major purpose of science is to produce new drugs and save lives.	4.4	4.5	0.1	4.4	4.3	-0.1
	26. Electronics are examples of the really valuable products of science.	2.2	2.0	-0.2	2.3	2.3	0.0
	27. A major purpose of science is to help people live better.	2.0	2.0	0.0	2.1	2.1	0.0
	30. Science tries to explain how things happen.	1.7	1.8	0.1	1.8	1.8	0.0
	Overall	2.6	2.6	0.0	2.6	2.6	0.0
C5	6. Scientific work is useful only to scientists.	3.1	3.4	0.3	3.4	3.5	0.1
	9. Most people are unable to understand science.	3.4	3.4	0.0	3.2	3.5	0.3
	14. Most people can understand science.	3.6	3.6	0.0	3.5	3.6	0.1
	15. Every citizen should understand science.	4.4	4.5	0.1	4.4	4.4	0.0
	24. Only highly trained scientists can understand science.	3.2	3.4	0.2	3.2	3.2	0.0
	25. People must understand science because it affects their lives.	4.2	4.1	-0.1	4.2	4.0	-0.2
	Overall	3.7	3.7	0.0	3.6	3.7	0.1

Table 6 continued

GF vs. comparison student response mean scores

		GF Average (n = 199)			Comparison Average (n = 117)		
Category	Items	Pre	Post	Diff	Pre	Post	Diff
C6	4. I would enjoy studying science.	4.0	3.8	-0.2	4.0	3.7	-0.3
	5. I may not make great discoveries, but working in science would be fun.	4.1	3.8	-0.3	3.9	3.6	-0.3
	10. Working in a science laboratory would be fun.	3.9	3.9	0.0	4.0	3.8	-0.2
	21. Scientists have to study too much.	3.1	3.2	0.1	2.9	2.9	0.0
	22. I would like to be a scientist.	3.4	3.3	-0.1	3.3	3.3	0.0
	23. The search for scientific knowledge would be boring.	2.9	2.9	0.0	3.1	3.0	-0.1
	28. I would like to work with other scientists to solve scientific problems.	3.6	3.6	0	3.4	3.5	0.1
	29. Scientists do not have enough time for their families or for fun.	3.5	3.6	0.1	3.7	3.4	-0.3
	31. Scientific work would be too hard for me.	3.5	3.5	0	3.4	3.2	-0.2
	32. I do not want to be a scientist.	3.1	3.2	0.1	3.0	2.9	-0.1
	Overall	3.5	3.5	0	3.5	3.3	-0.2



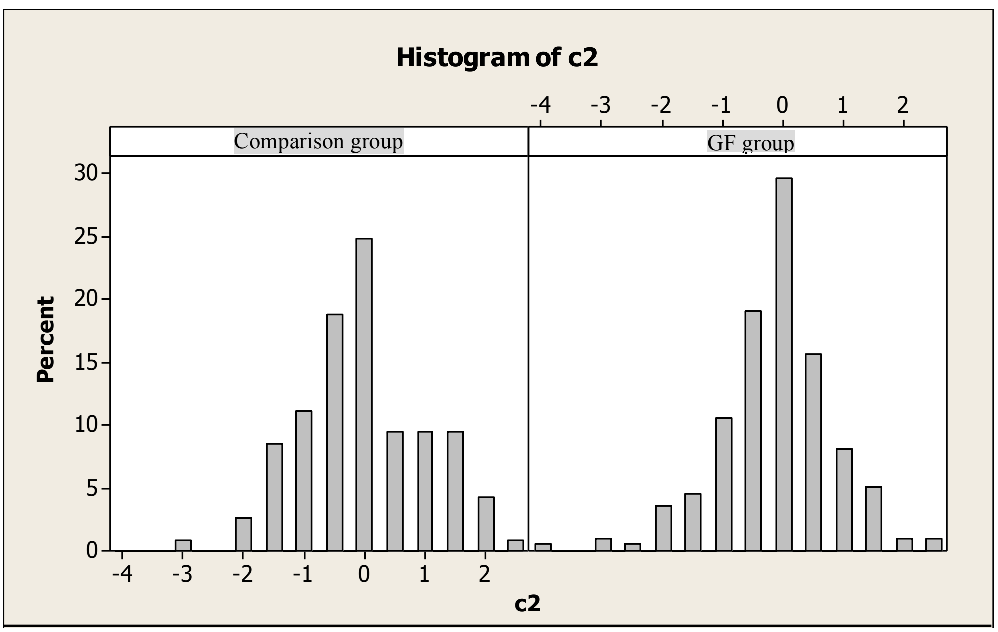
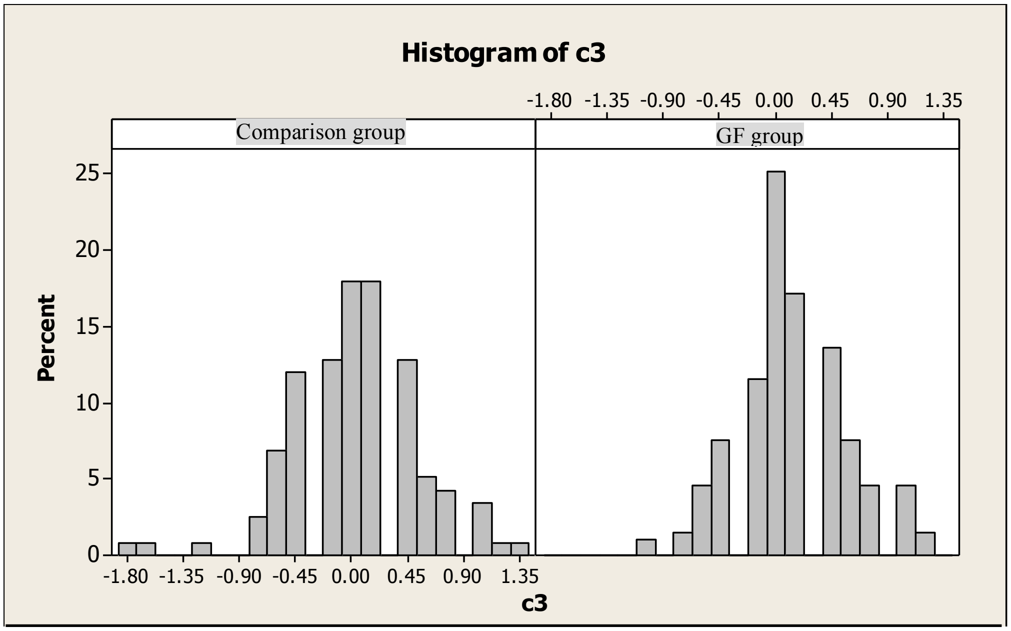


Figure 1. *Percent difference histograms for each SAI-II category for comparison and GF groups.*



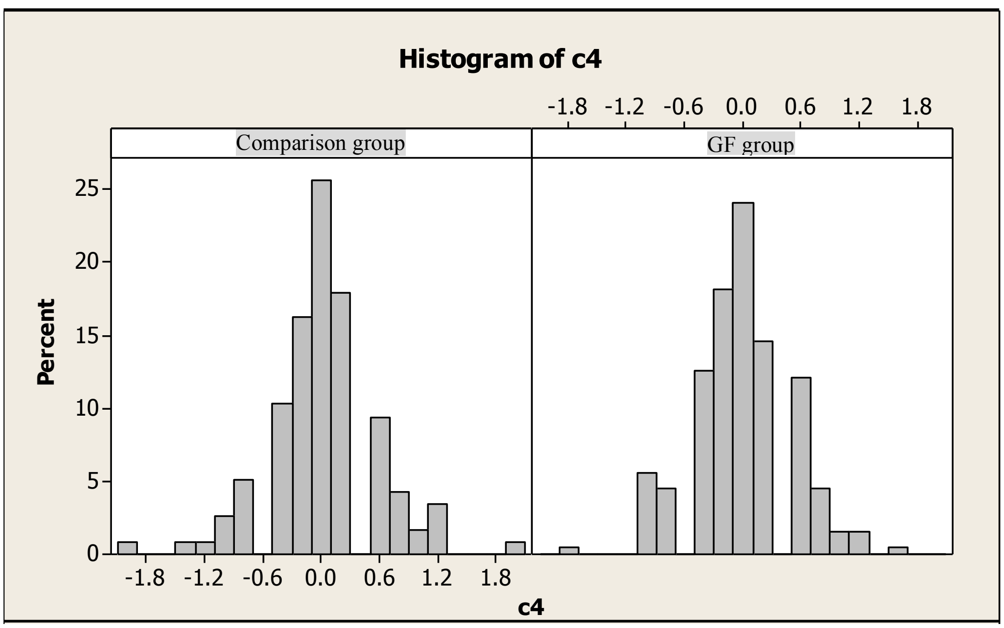
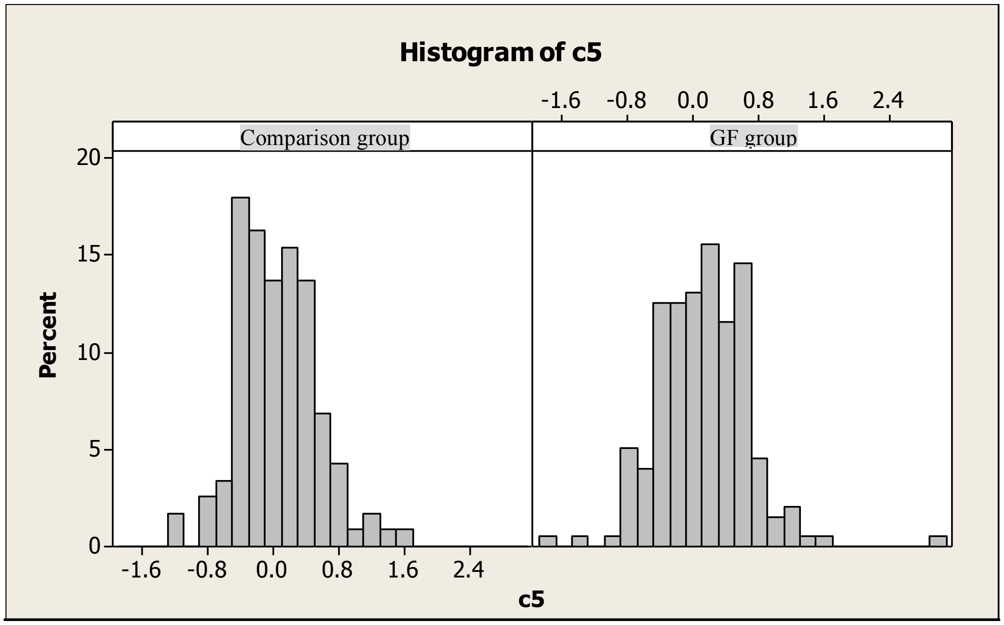


Figure 1 continued. *Percent difference histograms for each SAI-II category for comparison and GF groups.*



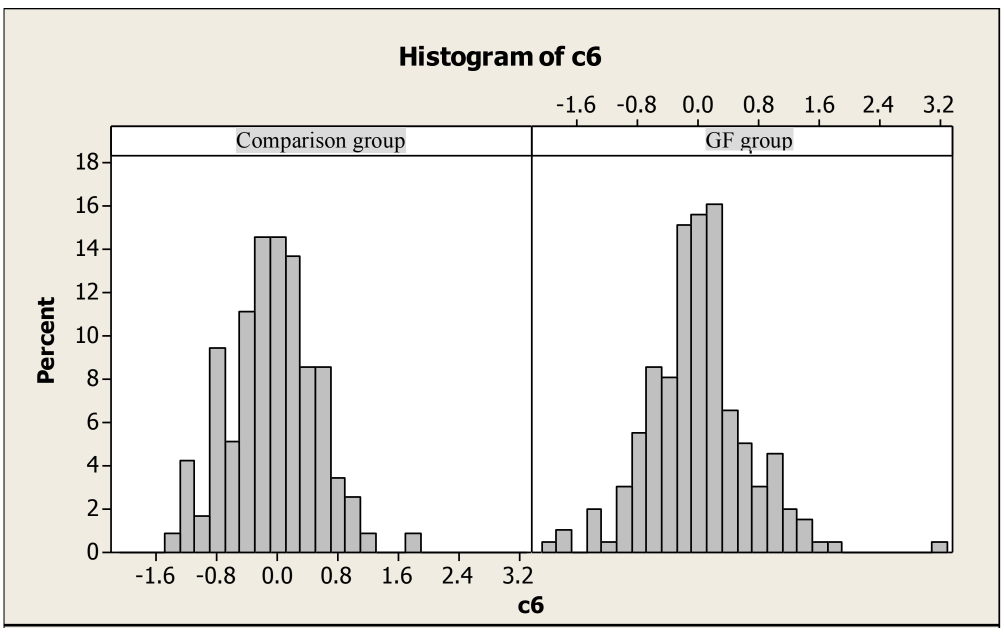


Figure 1 continued. *Percent difference histograms for each SAI-II category for comparison and GF groups.*

Directional changes in attitudes between the two groups can be viewed on an interaction plot of the mean differences for each group (Figure 2). Using the General Linear Model (GLM) procedure with the repeated measures Multivariate Analysis of Variance (MANOVA) procedure in SAS®, several hypotheses were tested while controlling for the fact that each subject responded to multiple questions in the survey, resulting in dependence of an individual's responses between the different categories. In particular, it tested for three things: a between student effect, a main effect for the different categories, and an interaction between the treatments (GF group and comparison group) and the categories. If this survey were taken by other students similar to these, a significant difference in the population average response of the change in responses over time for at least one of the categories would continue to be expected [F (5,310) = 5.23, p = .0001]. However, no significant difference in the population average change in survey responses for GF students and comparison students would be expected [F (1,314) =.58, p = .4455]. The largest difference for the sample from the GF group and comparison group in the average change in response (post – pre) was for C3 which had a sample difference of 0.0943 [F (1,314) = 3.17, p = .0761]. The GF group increase in C3, about characteristics needed by an individual to conduct science, is easily seen in Figure 2. Category 1 about the ability of science to change, and C5, about the importance of public understanding of science, also had slightly higher gains in attitude than the comparison group. Interestingly, C2, about the limitations of science, showed a negative change, more so than the comparison group. Both groups had slight declines in C6, about pursuing a science career, with the comparison group showing a larger decline than the GF group. Still using the repeated measures MANOVA, the interactions between the groups and categories were not considered significant [F (5,310) = 0.76, p = 0.5797].

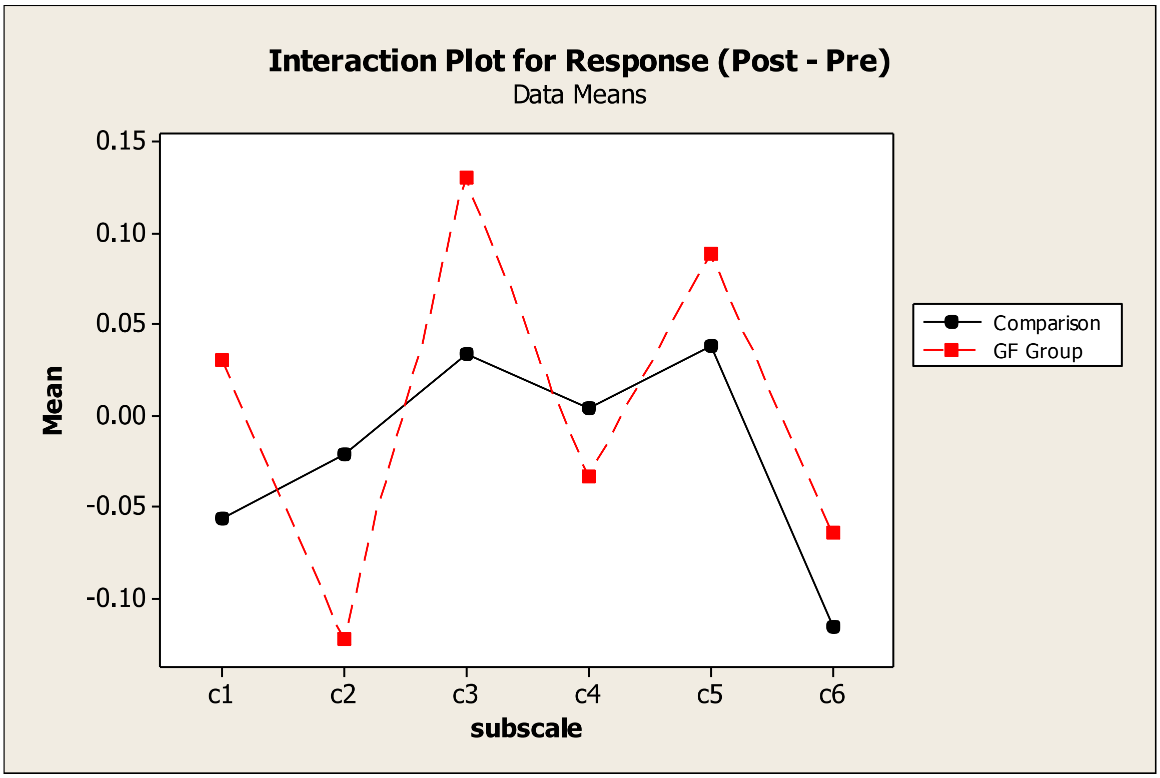


Figure 2. *Interaction plot response (post-pre) between treatment groups for mean differences in attitudes toward SAI-II categories.*

Cronbach's alpha reliability coefficient was calculated for pre-survey and post-survey SAI-II categories (Table 7). The total survey reliability values (Cronbach's alpha reliability coefficient pre = .8200) fall on the high end of the acceptable range (.70-.90), validating the reliability of the survey used in its entirety. For this study, the only category strong enough to have an acceptable reliability coefficient was C6.

Table 7
Pre-survey and post-survey reliability measures

	Cronbach's alpha reliability coefficient	
SAI-II Category	Pre	Post
C1	0.4414	0.4819
C2	0.5784	0.6682
C3	0.3417	0.4700
C4	*0.2748*	*0.2534*
C5	0.5813	0.6458
C6	**0.8670**	**0.8819**
Total Survey	**0.8200**	

Note: Bolded values fall within the acceptable range (.70-.90) for Cronbach's alpha reliability coefficient. *Italicized* values are farthest from the acceptable range.

Category 4 had the lowest reliability coefficients (pre = 0.2748, post = 0.2534). Further insight led us to reexamine the C4 results and post-results showed item 30 had inverted responses compared to the other items that make up C4 (Figures 3 and 4). When the Cronbach's alpha reliability coefficient was rerun eliminating item 30, the C4 value increased from 0.2534 to 0.4693.

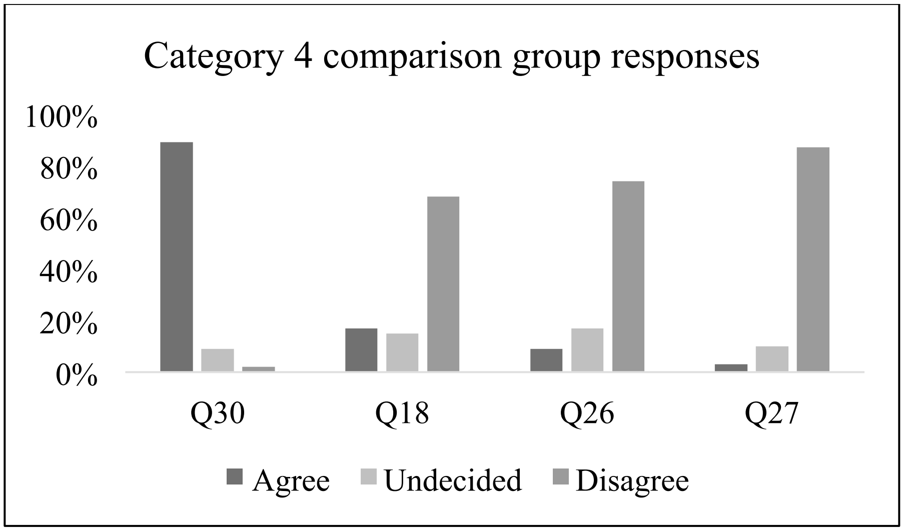


Figure 3. *Comparison group responses to SAI-II C4 items (questions).*

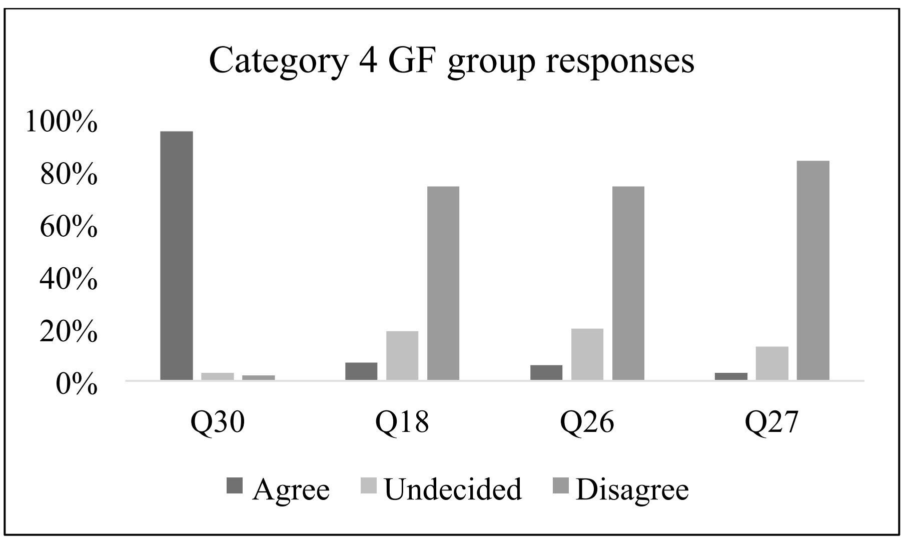


Figure 4. *GF group responses to SAI-II C4 items (questions).*

The SAI-II category differences can also be viewed by their variability. Variability of the category difference scores at a 95% confidence interval display a wider range in most categories of the comparison group than the GF group (Figure 5). While both groups have the most variability in C2, about the limitations of science, the comparison group's variability is much greater.

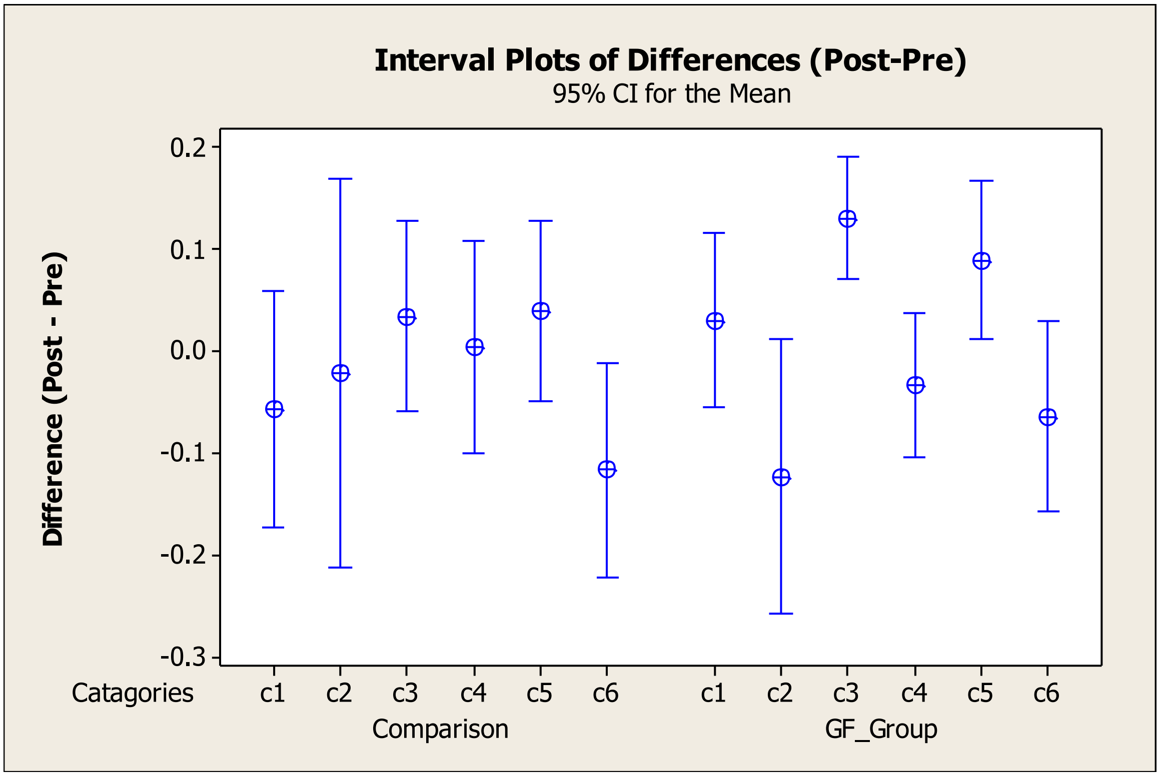


Figure 5. *Interval plots of SAI-II category differences (post-pre) for treatment groups at a 95% confidence interval.*

SAI-II Items

Contradictory responses to particular SAI-II items revealed student misconception about the nature of science and explanatory power (Table 6). Negative item 12, "When scientists have a good explanation, they do not try to make it better," responses directly contradicted the positive counterpart, item 8, "Scientists are always interested in a better explanation of things." The majority of GF and comparison students agreed with both items, and survey results show the misconception persisted throughout the year.

Student Career Interest

Career interest questions added to the SAI-II asked students to pick one area of career interest from 5 choices: Medicine, STEM teacher, non-STEM teacher, other STEM, and none of the above. The majority of GF students and comparison students chose medicine on both the pre and post surveys, followed by none of the above, other STEM, and both types of teachers (Figures 6 and 7). After one year interacting with a GF and completing research projects, GF students moved away from careers in STEM teaching, other STEM fields, and none of the above, and showed an increased interest in medicine and non-STEM teaching (Figure 8). Meanwhile, the comparison students changed career interest away from medicine, non-stem teaching, and none of the above, and increased interest in STEM teaching and other STEM fields (Figure 8).

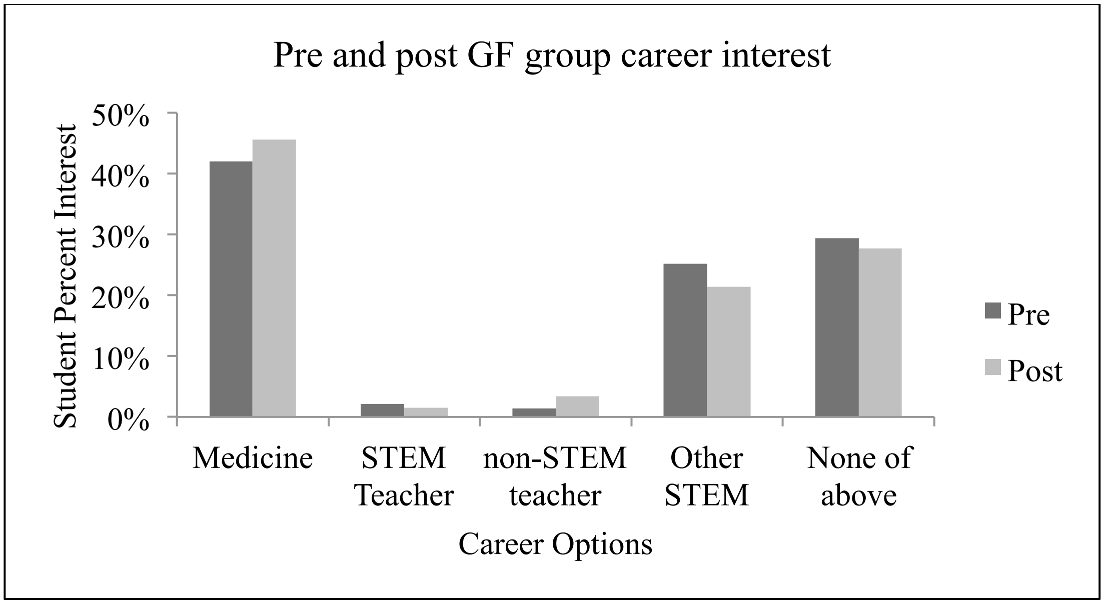


Figure 6. *Pre and post GF group career interest.*

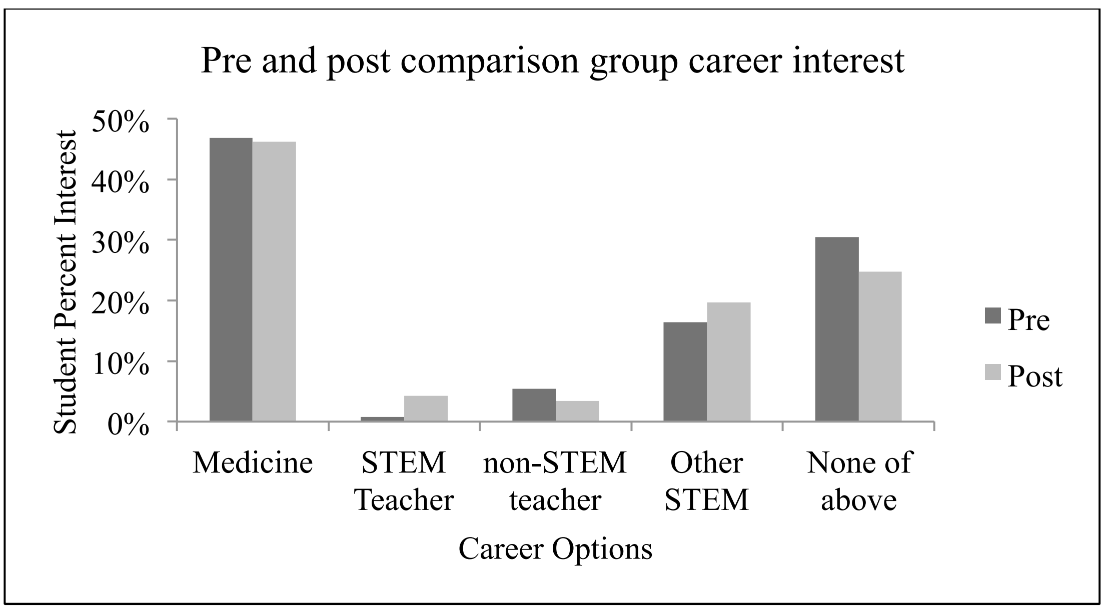


Figure 7. *Pre and post comparison group career interest.*

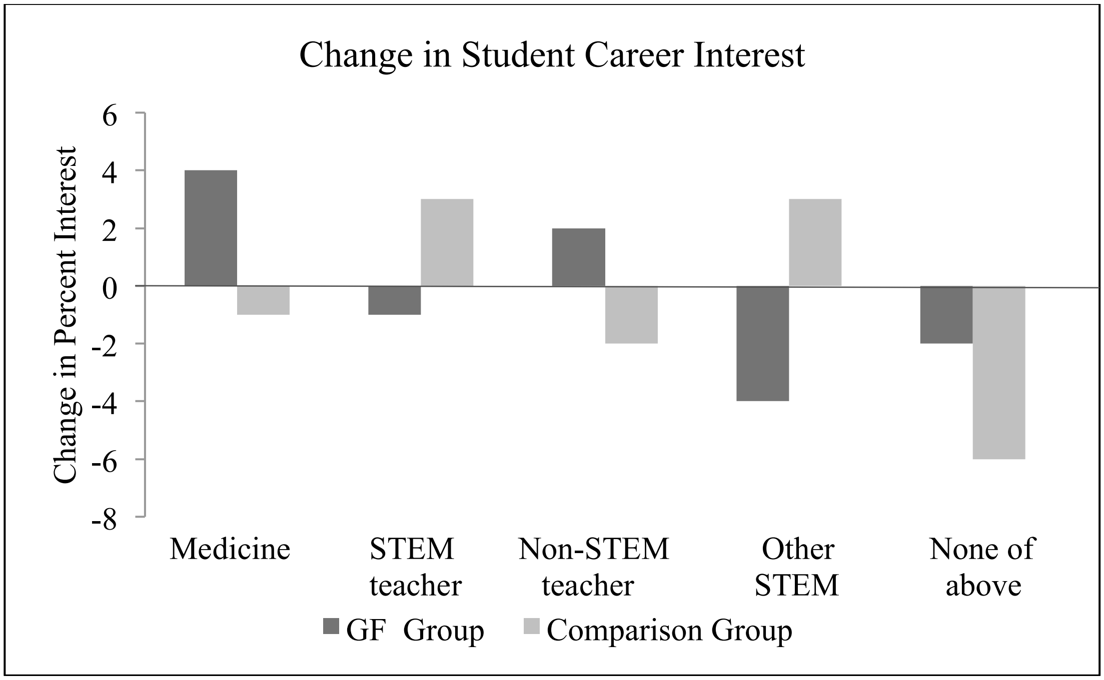


Figure 8. *Change in student career interest in treatment group after one year.*

Interviews

For the phenomenological study, student interviews with GF classes were recorded and transcribed verbatim, interview statements were extracted, common themes were assembled, and an overall description of the experience was written (see methods). From 15 verbatim transcripts, 17 interview statements were extracted. Table 8 contains student interview statements and corresponding common themes.

Theme 1, GF as a mentor, emerged from students describing the benefit of having a GF they could relate to while working on projects in the classroom. Theme 2, the scientific process, had the largest number of interview statements, with students explaining their new experiential knowledge of the timing, credibility, excitement, importance, and methodology that the scientific process involves. While one interview statement is shown for theme 3, communication, the frequency of this theme was also observed (Table 9) by students who mentioned talking to their parents, friends, or on social media about their experiences. The interview statement for theme 3 emphasizes the NSF's main goal for the GFs, to be able to communicate science to the public. This goal was achieved by a high school student who described being better able to communicate the science of the project to a judge after doing it multiple times to friends and family. Theme 4, changing versus a stagnant view of science, stemmed from student misconceptions noticed in the survey pre-data. This interview statement demonstrates a deeper understanding of the nature of science by distinguishing between science as a process and science as facts. Other interviewed students struggled to articulate this concept clearly. Theme 5, significance of the project, describes how students found the experience life-changing, thought it fun and exciting, believed school and science to be more interesting, and instilled an appreciation for the work of scientists. Many students mentioned a desire to have more projects like this and to do more science.

Table 8
Interview statements grouped by common theme

1. GF as a mentor
a. "I think it worked out pretty well. He talked to us on more of like instead of a teacher level on more of a student level and it related better to us."
b. "He was actually very entertaining, very intelligent. I loved learning from him. You could actually connect with him on a level to where you could understand what he was saying almost like a friendship almost."
2. Scientific process
a. "I learned that with experiments and generally wise you can't rush the process. You have to keep working at it and like make sure every detail is done that way you get the product you want at the end."
b. "Probably, I don't know how to phrase this, like honestly I used to just copy and paste things and cheat the way out and we do it like by the book and the right way now."
c. "I think it probably would've been slightly less exciting because we wouldn't have done all of this stuff. I thought it was really fun to actually do an experiment like this."
d. "I think we wouldn't have gotten to do as much science."
e. "I like definitely think I would've learned all of the AP Bio curriculum and stuff but my research project definitely wouldn't have been the same because it was like very helpful to have somebody that does research and can tell you like exactly what people that are in the science field would be interested in from your research."
f. "I definitely just kinda learned like how important research really is to science. Like that it's not just kinda like 'this is science and this is how it is' like it is always really important to question and keep studying."
g. "I definitely I feel like scientific literature was something that I was introduced to in a different way, um, just how easy that is to get knowledge that you know you have to experiment with is already there and can help you with your experiments so I think that's really useful."

Table 8 continued
Interview statements grouped by common theme

	h. "I think I don't science is like a body of knowledge its more I think it's more realistically like a method that you use to discovering knowledge of course our knowledge is always gonna be changing that's the best part about science but I definitely think it should be viewed as a process. Like you're doing science it's not like information."
3. Communication	
	a. "Yes. Maybe 5-10 times, I guess a lot of people didn't really understand it so you would have to talk about it a lot… Ya like today I started out kinda nervous but still like doing it and by the time the judge came by I think it was good."
4. Changing vs. static view of science	
	a. "Well technically science itself doesn't change but I guess the concepts and our understanding of it does because we are constantly learning new things."
5. Significance of project	
	a. "Not necessarily that we haven't covered. I mean it's like I said Jordan (pseudonym) was definitely awesome in helping us and I'm sure I can speak for everyone to say that was life-changing."
	b. "That I want to do more and like literally it's so much fun and exciting and it's better than like learning I mean it's a different way of learning that I feel like should be implemented a lot more."
	c. "I learned that school is not just like all work and stuff like you can have fun and still learn at the same time."
	d. "I think we should do this a lot more like projects like this cause I think like kids actually look forward to do this like it made me wanna come to class and wanna do my project so I think if a lot more of these kinda conventions went on that a lot more students would be interested in school."
	e. "Well it was kind of interesting to see how much time and work would go into this because at first I didn't think it would be, I thought it would be kind of easy, but to see how much effort went into this it can I dunno, help you see and appreciate what other scientists do."
	f. "It went really well. I learned a lot. It got me more interested in science than I was before and that was nice."

The common themes assembled from interview statements are also reflected in the frequency of student responses (Table 9). Among the 15 interviewees, theme 1, GF as a mentor, was mentioned 13% of the time. Theme 2, the scientific process, had a much higher frequency being mentioned 53% of the time. Theme 3, communication, is reflected in students mentioning their projects to their family (80%), their friends (73%), and posting about it on social media (27%). Theme 4, changing versus a stagnant view of science, was responded to by all students, and therefore not included in the table. Lastly, theme 5, significance of the project, can be observed in many of the responses including useful (33%), fun (27%), and boring without the experience (20%). Based on interview statements, common themes, and frequencies, the phenomenological study demonstrates students having a positive and beneficial experience while participating in the GK-12 program.

Table 9

Frequency of interviewed GF student responses

Frequent student responses	Number of times mentioned by each student															Total	% of times mentioned
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15		
Attend college	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	100
Mentioned to family		1	1	1	1		1	1		1	1	1	1	1	1	12	80
Projects difficult without GF	1				1	1	1		1	1	1	1	1	1	1	11	73
Mentioned to friends	1		1			1	1	1		1	1	1	1	1	1	11	73
Interest in science major/field	1	1				1	1	1	1	1	1	1		1	1	11	73
Scientific process appreciation/ understanding	1	1			1				1	2	2	2		1		11	53
Useful		1				1					1	1		1		5	33
Fun				1				1				1	2			5	27
Posted on social media				1						1		1	1			4	27
Boring without the experience		1	1					1								3	20
GF as a mentor	1	1														2	13

IV. DISCUSSION AND CONCLUSIONS

The purpose of this study was to determine the effect of Biology graduate student interactions on high school student attitudes toward science and career choice. Guiding questions 1-3 focused the study on the GF student increases (C1, C3, and C5) and decreases (C2 and C4) in aspects of their attitudes toward science. Misconceptions about scientists' explanations, guiding question 3, remained in both groups. Guiding question 4, focused on career interest, found both groups decreased in STEM career interest, with a larger decrease in the comparison group. GF student perceptions about their research experience, guiding question 5, conveyed increased understanding of the scientific process and a desire to continue practicing science. Overall, while GF classes actively participated in meaningful STEM experiences, the challenges in changing student attitude about science and increased pursuance of STEM careers are evident.

SAI-II Categories

The SAI-II and student interview responses were used to answer guiding question one which asks *after interaction with a graduate fellow, what aspects of student attitudes toward science will increase?* In this study the positive directional changes in attitudes between the GF and comparison groups show the GF group had a greater increase in attitude in C1, C3, and C5. Category 1 states "The laws and/or theories of science are approximations of truth and are subject to change." After completing a research project with GF mentorship and learning about the GF's graduate research, GF students got more experience developing questioning skills and viewing previous research with a critical eye which would improve their attitudes to C1. The interview statement 2f, "… it is always really important to question and keep studying," highlights this idea (Table 8).

Positive changes in the GF group were also seen in C3, which states "To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one's position on the basis of sufficient evidence." Again, this category directly measures attributes associated with research experience as well as the scientific process, a common theme from the phenomenological study. Through student observations about the power of honesty, objectivity, and use of evidence in science consistently reinforced in the classroom by the GF, this modeled for the students how to approach their own science research projects. Acquisition of intellectual honesty is demonstrated in interview statement 2b, "… I used to just copy and paste things and cheat the way out and we do it like by the book and the right way now." The attributes of science in C3 are major components of the nature of science, which is notoriously a difficult concept to teach (Flick & Lederman, 2006). Classes with a GF benefited from learning about the nature of science throughout the school year not only through discussions about the GF's research but also by designing and conducting their own research project.

A slight increase in GF student attitudes was also seen in C5, "Progress in science requires public support in this age of science; therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work." The classroom research experience mentored by the GF allowed many students to make real-world connections between their research and its possible extensions, placing an emphasis on the fact that the public benefits from scientific work. After involvement in project-based learning with an authentic science research project, students that previously struggled to get through science class became excited to participate (interview statements 5b-e, Table 8). These methods increased their own understanding of science (Hoftsein & Lunetta, 1982; Flick & Lederman, 2006), which may have increased their attitudes about the importance of the public being able to understand science. The ability to communicate science, a common theme from the phenomenological study, also plays a role in the understanding of science by the general public. GF students presented their research at multiple venues including the TRIAD Research Symposium and the Tennessee Junior Academy of Science. While the goal of the NSF was for GFs to become better communicators of science, interview statement 3a signifies this was a benefit some GF students achieved (Table 8). A student having the ability to communicate their research to the public would most likely impact their views on the ability of the public to understand science. Lacking these experiences, the comparison group's gains in this category were not as large.

The SAI-II and student interview responses were used to answer guiding question two which asks a*fter interaction with a graduate fellow, what aspects of student attitudes toward science will decrease?* While the GF group had a larger increase in attitude in C1, C3, and C5, their attitude toward C2 and C4 declined more than the comparison groups. Category 2 involves ability of science to answer questions, which is what the GF students had experience doing. C2 states, “Observation of natural phenomena and experimentation is the basis of scientific explanation. Science is limited in that it can only answer questions about natural phenomena and sometimes it is not able to do that.” It is possible the GF students had a larger decline in this category than the comparison group because after completing their research projects, they felt a heightened confidence that anything could be answered through science, not realizing the limitations that exist in science. In 2006, Stake found that science motivation and confidence was increased by social encouragement from family, teachers, and peers. Increased social encouragement is evident by the GF student interview responses (Table 9), with many interviewees discussing their projects with family (80%), friends (73%), and even posting on social media (27%). An extra layer of social encouragement is provided by the GF as a mentor (interview statements 1a-b), boosting student confidence in their ability to complete their projects, and, therefore, potentially boosting their view that science and answer anything. Without a project to discuss with friends and family and an extra encouraging mentor in their classroom, the comparison group would not display this heightened confidence. However, C2 also displayed the largest range of variability for both the GF and comparison groups, highlighting student inability to decipher what science can and cannot answer, another major aspect of the nature of science. While GF students had increased attitudes on one aspect of the nature of science, C3 which is about attributes of science and scientists, they displayed lowered attitudes and a large amount of variability in their attitudes toward the limitations of science. According to Flick and Lederman

(2003), solely inquiry-based instruction has not been able to consistently improve student understanding of the nature of science. Previous research by Kishfe & Abd-El-Khalick (2002) also found that explicit instructional strategies that teach about the nature of science are necessary since students have difficulty discerning the nature of science from simply doing science activities. Incorporating lessons that explicitly addressed the nature of science along with the research projects may have improved student attitudes about science as measured by the SAI-II.

The purpose of C4 is to determine student ability to differentiate science and technology, stating "Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects." The results show that both the GF group and the comparison group have misconceptions in this category. The items in C4 talk about the purpose of science, and the majority of students agreed that involves new technologies, drugs, and things that make our lives better. The differentiation between science and technology is difficult to teach and was not directly applied during the research projects. Another explanation for the majority of students responding as uncertain to C4 is the items need to be brought into 21st century vocabulary about what is technology. The SAI was first developed in 1970 and underwent minor changes in 1997 to become the SAI-II (Moore & Foy, 1997). Most of the revisions dealt with difficult vocabulary and gender bias. Hugh Munby analyzed thirty different studies that used the first SAI in 1981 and, when looking at each category individually, found that C4 may act as a "conceptual contaminant" in the instrument (p. 37). He identifies vocabulary such as "products" in the SAI (still present in the SAI-II) that is ambiguous and could affect student responses. Later, in 1992, Aikenhead and Ryan developed a new instrument, "Views on Science-Technology-Society" (VOSTS) that addresses the SAI-II C4 concept about the relationship between science and technology more concretely. This study particularly found item 30 to be incongruous with the other items due to a higher reliability coefficient for the category when it was removed. The ambiguous findings from this study suggest that perhaps C4 content items should be revisited and revised.

SAI-II Items

The SAI-II was used to answer guiding question three which asks a*fter interaction with a graduate fellow, how did recognized student misconceptions change?* A major misconception emerged from both groups of students agreeing with contradicting items about scientists' desire to better explanations. Because the GF group and the comparison group strongly held this misconception throughout the year, interactions with the GF and their research experience did not have an impact that was able to positively shift this misconception. Students are taught that scientists approach their scientific work with a critical eye, yet information is presented to students as facts in textbooks to learn and regurgitate on state tests. Students do not hear of scientists critically evaluating their own and other scientists' research, looking for a better explanation. They do hear of scientists looking for better gene therapy methods or cures for cancer but it appears they don't see this as a search for a better explanation. Graduate fellow classes learned about the peer review process through their own research projects but they apparently did not connect that with the item stated that scientists critically evaluate each other's work. Therefore, this misconception may have occurred because even though they know that scientists have a selective critical eye it could be they misunderstood the intention of this survey item.

Student Career Interest

The SAI-II and added career questions were used to answer guiding question four which asks a*fter interaction with a graduate fellow, how did student attitudes about pursuing a career as a scientist change?* Two areas of the study investigated student career interest, C6 and added survey items. Category 6, about interest in and desire to pursue a science career had a decreased interest for both groups. However, the comparison group had a larger decrease than the GF group, meaning that the defined decrease in pursuance of a STEM career was slightly reduced in these students. The added survey items showed that the majority of both groups of students desired a career in medicine. Interestingly, the largest increased interest for GF students was in medicine while comparison students had an increased interest in STEM teaching and other STEM fields. It may be that after interacting with a GF and completing their research projects GF students better understood the challenges involved in industry and research STEM careers, and possibly thought them to have a high risk of failure, and therefore, avoided choosing those fields as their interest (Osborne et al., 2003). However, if they still had an interest in a science, students could choose medicine instead, considering it to be in the same field. Other possibilities include medicine being easy to relate to or GFs with an interest in biomedical fields influencing the career interests of GF students. Meanwhile, learning about different biotechnologies and STEM fields and not interacting with them may be why comparison students showed increased interest in those fields. This decrease in interest in a STEM career reflects previous research that student attitudes toward science decline during their high school years (George, 2006; Yager & Penick, 1986; Simpson & Oliver, 1985; Breakwell & Birdsell, 1992; Galton, Gray, & Ruddock, 2003), fewer high school students pursue STEM majors in college (Masnick et al., 2010; Hossain & Robinson, 2012; Wyss & Tai, 2012; PCAST, 2012) and there is a lack of STEM workforce compared to the growing economic demand (George, 2003, Hossain & Robinson, 2012; Wyss & Tai, 2012).

Interviews

Student interview responses were used to answer guiding question two which asks a*fter interaction with a graduate fellow, what aspects of student attitudes toward science will decrease?* The phenomenological portion of the study uncovered 5 common themes that the GF students experienced: (1) GF as a mentor, (2) the scientific process, (3) communication, (4) changing verses stagnant view of science, and (5) significance of the project. The first theme confirms that the GFs enthusiasm for their own research and assisting with the student research succeeded as mentors (Masnick et al., 2010; Raju & Clayson, 2011). Working with GFs improved student views of the scientific process (theme 2) in a way they would not have received without the GF. Many students not only enjoyed their research, but desired more in future science classes for themselves and for other students to experience. An appreciation for the process of science, scientists, and scientific literature developed after participating in the scientific process themselves. Communication, theme 3, ties into the scientific process the students experienced by presenting their research at various symposiums. After explaining their research many times to family and friends, students got better at communicating their research, the same goal the NSF had for the GFs. This talent allowed them to convey their views on theme 4, changing vs. stagnant view of science. Many students said that science changes but few students were able to articulate that while science as a body of knowledge is always changing, the process of science stays the same (interview statement 2h, Table 8). Many other aspects of the projects had positive effects on the GF students, and their descriptions of these are assembled in theme 5, significance of the projects. The experience excited students, made them look forward to science, and instilled in them an appreciation for the importance of research and scientists. The majority of students expressed a desire for GK-12 like programs to be implemented in their future classes, and continue in current classes so that other students can benefit from the experience.

Limitations and Implications

SAI-II category analysis confirms there was no significant difference between the GF group and the comparison group after one school year. The observed differences were very close to zero, showing no significant positive changes in student attitudes toward science. Yet while there was extra time required in the curriculum for implementation, there is no indication of a negative effect from survey data. The similarity between the

GF and comparison group post-survey results also point out there was no interference to the normal growth that occurs throughout the school year. Meanwhile, qualitative results show positive aspects of science attitudes across the board. These contradicting results may be due to the difficulty related to changing attitudes and/or the instrument chosen to assess student attitudes.

Formed and declining during the early secondary years, attitudes toward science are extremely difficult to change (Bennett & Hogarth, 2009; Simpson & Oliver, 1985; Ajzen & Fishbein, 1980; Harvey & Edwards, 1980; Osborne et al., 2003). Graduate fellow interactions were implemented at the secondary level with the intention of changing the attitudes of high school students. However, with no change observed after one year of implementation with the SAI-II, it is possible a longitudinal study over a longer period of time would be better able to quantify the positive attitudes seen in the qualitative data. In 2006, Tai analyzed longitudinal data provided by the National Center for Educational Statistics and found that 8^{th} grade students already interested in science stayed interested and pursued science careers. Meanwhile, of 8^{th} graders that picked non-science careers, few went into science. This implies that substantial career deciding experiences happen before 8^{th} grade, and it is possible that implementation of project-based learning like GK-12 provides needs to start sooner and last longer (Tai, 2006).

Some attitude components cannot be measured using surveys like the SAI-II. The GF student interview data confirms this with students declaring positive attitude statements after experiencing the research process. Multiple GF students had papers accepted and presented their research at the Tennessee Junior Academy of Science, a very prestigious state group affiliate of the American Academy of Science that selects papers submitted from all the schools in the state by a panel of college professors. In addition, all GF students presented their research at either the TRIAD symposium or at their school to peers and the public. These great achievements and experiences reflected in the qualitative data are not shown in the survey data. Because video recording of daily interactions were not collected as part of the study, the possible richness of the role the GF played in the classroom cannot be known.

Another possible reason the survey data findings conflict with the phenomenological study is the SAI-II instrument. The modified SAI-II was used to determine change in student attitude toward science has been widely used, validated, and tested for reliability. It was used in this study for these reasons, given the large number of secondary students participating. However, after implementing this instrument and further research, it appears there is debate over how well it is able to quantify student attitudes. Previous research using the instrument shows similar results to those of this study, with few to no significant differences in the categories (Cole, 2009; Gallucci, 2007) and difficulties maintaining an acceptable Cronbach's alpha value (Hampton, 2007). The instrument has undergone several evaluations by various researchers that have discovered issues in its validity. The original SAI content was not altered during the first revision of the SAI, and the SAI-II content validity is based on the original SAI panel of judges from 1970 (Munby, 1997). Munby tested these categories using factor analysis and found the results eliminated the original SAI judges' validity statements (1997). A larger study completed in 2008 also retested the psychometric properties of the SAI-II (Lichtenstein, Owen, Blalock, Liu, Ramirez, Pruski, Marshall, & Toepperwein, 2008) coming to the same conclusions as Munby, that factor analysis proved the categories insignificant. Rather than the original six categories in the SAI-II, three new, different categories were suggested instead: (1) "Science is about understanding and explaining," (2) "Science is rigid," and (3) "I want to be a scientist," (Lichtenstein et. al., 2008). Validation of these three categories may increase the reliability of the SAI-II and improve its use in educational studies in the future.

In conclusion, after one year of GF mentorship and research project completion, GF students did not have significant increases in their attitudes toward science; yet, they had an increased interest in medical careers, felt they better understood the scientific process, and wanted to continue practicing science. This implies that in future studies, challenges in changing student attitude about science and increased pursuance of STEM careers may be addressed by assessing daily classroom interactions, lengthening the study into a longitudinal format, using different categories suggested for the SAI-II, or using an alternative instrument to assess student attitude toward science.

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APPENDICES

APPENDIX A

Derived SAI-II Survey with IRB Approval and Student Assent Statement

MTSU
IRB Approved
Date: 8/29/13

Print Name ____ Age ________

We are doing a study to determine high school student attitude about science and related careers. No personal information other than your name and survey responses about science and career choice will be collected. Once responses are matched, your name will be permanently removed from the record. You do not have to participate in the study, but you may need to complete the survey as part of a class assignment. You can change your mind about participating at any time. If you do not want to participate, your answers will not be collected for the study. If you have any questions, you can ask your teacher or your graduate fellow.

Please sign below if you agree to participate.

____ ____________________
Signature of Student Date

WHAT IS YOUR ATTITUDE TOWARD SCIENCE?

There are some statements about science on the next three pages. Some statements are about the nature of science. Some are about how scientists work. Some of these statements describe how you might feel about science.

You may agree with some of the statements and you may disagree with others. That is exactly what you are asked to do. By doing this, you will show your attitudes toward science.

After you have carefully read a statement, decide whether or not you agree with it. If you agree, decide whether you agree mildly or strongly. If you disagree, decide whether you disagree mildly or strongly. You may decide that you are uncertain or cannot decide. Then, find the letter of that statement on the answer sheet, and **SHADE** the number on your scantron:

EXAMPLE:

Question	Agree Strongly	Agree Mildly	Uncertain	Disagree Mildly	Disagree Strongly
1. I would like to have a lot of money.	A	B	C	D	E

SCANTRON:

A B C D E
1 ● ② ③ ④ ⑤

The person who selected this example agrees strongly with the statement, "I would like to have a lot of money," because they bubbled the letter A on their scantron sheet.

SURVEY STARTS HERE

1. Do/did you have a scientist from MTSU in your classroom this year?	**A.** Yes	**B.** No
2. Currently, it is:	**A.** Fall	**B.** Spring

Question	Agree Strongly	Agree Mildly	Uncertain	Disagree Mildly	Disagree Strongly

Derived SAI-II Survey (continued)

Science Attitudes Survey

3. Good scientists are willing to change their ideas.	A	B	C	D	E
4. I would enjoy studying science.	A	B	C	D	E
5. I may not make great discoveries, but working in science would be fun.	A	B	C	D	E
6. Scientific work is useful only to scientists.	A	B	C	D	E
7. Scientific ideas may be changed over time.	A	B	C	D	E
8. Scientists are always interested in better explanation of things.	A	B	C	D	E
9. Most people are unable to understand science.	A	B	C	D	E
10. Working in a science laboratory would be fun.	A	B	C	D	E
11. Some questions cannot be answered by science.	A	B	C	D	E
12. When scientists have a good explanation, they do not try to make it better.	A	B	C	D	E
13. Scientists should not criticize each other's work.	A	B	C	D	E
14. Most people can understand science.	A	B	C	D	E
15. Every citizen should understand science.	A	B	C	D	E
16. Scientific questions are answered by observing things.	A	B	C	D	E
17. Anything we need to know can be found out through science.	A	B	C	D	E
18. A major purpose of science is to produce new drugs and save lives.	A	B	C	D	E
19. If one scientist says an idea is true, all other scientists will believe it.	A	B	C	D	E
20. Scientists must report exactly what they observe.	A	B	C	D	E
21. Scientists have to study too much.	A	B	C	D	E
22. I would like to be a scientist.	A	B	C	D	E
23. The search for scientific knowledge would be boring.	A	B	C	D	E
24. Only highly trained scientists can understand science.	A	B	C	D	E
25. People must understand science because it affects their lives.	A	B	C	D	E
26. Electronics are examples of the really valuable products of science.	A	B	C	D	E
27. A major purpose of science is to help people live better.	A	B	C	D	E
28. I would like to work with other scientists to solve scientific problems.	A	B	C	D	E
Question	**Agree Strongly**	**Agree Mildly**	**Uncertain**	**Disagree Mildly**	**Disagree Strongly**

Derived SAI-II Survey (continued)

Science Attitudes Survey

29. Scientists do not have enough time for their families or for fun.	A	B	C	D	E
30. Science tries to explain how things happen.	A	B	C	D	E
31. Scientific work would be too hard to me.	A	B	C	D	E
32. I do not want to be a scientist.	A	B	C	D	E
33. Indicate your gender.	**A**. Male **B**. Female				
34. Indicate your class status in high school this year.	**A**. Freshman **B.** Sophomore **C**. Junior **D**. Senior				
35. Select one group that best represents your most likely career choice. If not listed here, select **none of the above.**	A. Medical/Health Care Profession B. Teacher – Science, engineering, technology or math subject C. Teacher - other subjects than listed in the previous answer D. Science, engineering, technology or math area other than teacher or health care E. None of the above				
36. Select one group that best represents your most likely career choice. If not listed here, select **none of the above.**	**A.** Business/finance **B.** Art/Music/English/History/Languages **C.** Psychology/Sociology/Social Work **D.** Law/Political Science **E.** None of the above				
37. Do you plan to attend college?	**A.** Yes **B.** No				
38. If you plan to attend college, what would you like to study?	**A.** Biology/ Physical Science/ Chemistry **B.** Technology (computers) **C.** Engineering **D.** Mathematics **E.** None of the above				
39. If you do not plan to attend college when you graduate from high school, then what do you plan to do?	**A.** Get a job **B.** Attend a technical school **C.** Join the Military **D.** Something else not mentioned here **E.** I do plan to attend college.				

APPENDIX B

IRB Approval

MIDDLE TENNESSEE STATE UNIVERSITY

June 4, 2013

Drs. Kim Cleary Sadler, Anthony & Mary Farone, Ginger Rowell
Co investigators: Ms. Rachel Lytle, Mr. Patrick Phoebus, Karen Case
Department of Biology
ksadler@mtsu.edu ; afarone@mtsu.edu , mfarone@mtsu.edu , rowell@mtsu.edu

Protocol Title: "TRIAD: High School Student Perception of Science, Scientists, and Career Choice After One Year in the Classroom with a GK-12 Fellow"

Protocol Number: **13-021**

Dear Investigator(s),

I have reviewed your research proposal identified above and your request for continuation and your requested changes. Approval for continuation is granted for one (1) year from the date of this letter. Any changes to the originally approved protocol must be provided to and approved by the research compliance office.

You will need to submit an end-of-project report to the Office of Compliance upon completion of your research. Should the research not be complete by the expiration date, **June 4, 2014**, please submit a Progress Report for continued review prior to the expiration date.

According to MTSU Policy and Procedure, a researcher is defined as anyone who works with data or has contact with participants. Therefore, should **any individuals be added to the protocol that would constitute them as being a researcher, please identify them and provide their certificate of training to the Office of Compliance**. Any change to the protocol must be submitted to the IRB before implementing this change.

Please note that any unanticipated harms to subjects or adverse events must be reported to the Office of Compliance at (615) 494-8918.

Also, all research materials must be retained in a secure location by the PI or **faculty advisor (if the PI is a student) for at least three (3) years** after study completion. Should you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,

Kellie Hilker
Compliance Officer
Research Compliance Office
494-8918
Compliance@mtsu.edu

APPENDIX C

IRB Parental Consent Form

MTSU
IRB Approved
Date: August 16, 2013

Principal Investigators: Drs. Kim Sadler, Anthony & Mary Farone, Ginger Rowell
Co-Principal Investigators: Rachel Lytle & Patrick Phoebus
Study Title: TRIAD – Reforming Graduate Education by Integrating Teaching, Research, and Industry Applications to Deepen Scientific Understanding
Institution: Middle Tennessee State University

Name of student: ____ **Age**: __________

The following information is provided to inform you about a research study and your child's participation in it. Please read this form carefully and feel free to ask any questions you may have about this study and the information given below. You will be given an opportunity to ask questions, and your questions will be answered. Also, you may request a copy of this consent form.

Your child's participation in this research study is voluntary. He or she is also free to withdraw from this study at any time. In the event new information becomes available that may affect the risks or benefits associated with this research study or your willingness to participate in it, you will be notified so that you can make an informed decision whether or not to continue your participation in this study.

For additional information about giving consent or your rights as a participant in this study, please feel free to contact the MTSU Office of Compliance at (615) 494-8918.

1. **Purpose of the survey:**
   Your child is being asked to complete a survey and possibly answer interview questions because MTSU is examining the impact of a graduate student 'scientist in residence' in high school science classrooms.
2. **Description of procedures to be followed and approximate duration of the study:** Students will complete a 40-item survey during class. The student survey will be given twice, once in the early fall and once in late spring. Students may be given the option to answer interview questions about their experiences in science class this year.
3. **Expected costs:**
   There will be no cost to the parent, child, or teacher. The TRIAD project is funded by the National Science Foundation (NSF).
4. **Anticipated benefits from this study:**
   The anticipated benefits from this study include:
   Enriched learning by high school students; increased interest in science, technology, engineering, and math (STEM) disciplines and careers.
5. **What happens if you choose to withdraw from survey participation:** There is no consequence for withdrawing from participation in completing the survey..
6. **Contact Information.** If you should have any questions about this survey, please feel free to contact:
   Dr. Kim Sadler 615-904-8283 Kim.Sadler@mtsu.edu
   Rachel Lytle 615-812-0135 rrl2j@mtmail.mtsu.edu
7. **Confidentiality.** No personal information other than your child's name and survey responses about science and career choice will be collected. Once responses are matched, your child's name will be permanently removed from the record. Anonymous responses may be shared with MTSU or the government, such as the Middle Tennessee State University Institutional Review Board, Federal Government Office for Human Research Protections, *if* you or someone else is in danger or if we are required to do so by law.
8. **STATEMENT BY Parent AGREEING TO ALLOW Child to PARTICIPATE IN THIS STUDY**
   I have read this informed consent document. I understand each part of the document, all my questions have been answered, and I give permission for my child to complete the survey for the study.

_________________ ______________________________
Date Signature of Parent

Consent obtained by:

_________________ ______________________________
Date Signature

____
Printed Name and Title

APPENDIX D

Permission for Use of SAI-II

-----Original Message-----
From: Richard Moore [mailto:moorerw@muohio.edu]
Sent: Friday, March 09, 2007 1:32 PM
To: mrutledg@mtsu.edu
Subject: Re: Use of SAI II

Dr. Rugledge, I have attached a copy of the SAI II and a copy of a document listing the positions assessed by the various items in the SAI II. You can use the latter to score the former. Regretfully the computer program I used is no longer workable. Permission to use the instrument in your current work is hereby granted. Best wishes with your work.

Richard W. Moore