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Science Teachers' Understandings of Science Practices before and after the Participation in an Environmental Engineering Research Experiences for Teachers (RET) Program

by

Dilek Özalp

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
with a concentration in Science Education
Department of Teaching and Learning
College of Education
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Keywords: apprenticeship, community of practice, epistemic community, methodological proficiency, intellectual proficiency, mixed methods research

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DEDICATION

To my mom Zeynep Özalp

My dad Cemil Özalp

And my brother Murat Özalp

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I would like to take the opportunity to express my thanks to many people for their help, support, and encouragement in completing my dissertation and my graduate education.

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ABSTRACT

In 2012, National Research Council published a new science education framework that explains the science practices and its importance in understanding the process of knowledge development. The students were expected to engage in all the practices by grade 12. All science teachers need some kind of support to improve their understandings of these science practices (NRC, 2012). An important key component of engaging teachers in scientific investigations is to have the teacher participate in a research laboratory experience (NRC, 1996). Research Experiences for Teachers programs (RET) serve as a promising form of professional development to achieve this goal. These programs allow teachers to experience scientific inquiry (Blanchard, Southerland, & Granger, 2009; Roseler, Nguyen, Golden, & Southerland, 2012).

The main goal of engineering and computer science RET programs is to create collaborative partnerships between K-12 STEM teachers and university faculty by involving them in engineering and computer science research and helping the teachers translate their research experiences and new knowledge into classroom activities. However, the problem is that we do not know what teachers actually learn about science practices in the RET programs. This study addressed this problem and provided findings about science teachers' understandings of science practices before and after they participated in an environmental engineering RET program. In addition, teachers' abilities engaging in science practices were examined to provide a complete picture of the results. This research also determined the sources of the differences of teachers' changes in their understandings of science practices and their abilities engaging in science practices to provide more insightful results for the study.

The context of the study was a Research Experiences for Teachers (RET) program supported by National Science Foundation It was located in an United States university Environmental Engineering program. There were five preservice and ten inservice teachers in this research. In addition, there were six professors and eight graduate students who served as mentors. Each teacher worked with a specific professor and graduate student mentor in their research projects that are related to the management of the nitrogen cycle, provision of clean water, or urban infrastructure improvement. Also, four professors from engineering and science programs were interviewed to find out what each science practice means to them. The research design of this study was mixed methods that combined quantitative and qualitative research approaches into a single study. In this study, two teachers were selected for the case study based on their experiences and improvements. The study utilized different data sources such as surveys, interviews, observations, and documents. Each research question was addressed based on the results of overall analysis of all the teachers, as well as the results of each case. To find out whether there was a statistically significant difference between the pre-, mid-, and post teacher surveys, repeated measures ANOVA was used for each item. In addition, for the items that showed a statistical difference a Tukey test was conducted to find -which surveys -were significantly different from each other. Also, partial eta squared effect size was calculated for each item. Professor and graduate students' surveys were analyzed by a repeated measures ANOVA and Tukey tests. All interviews were transcribed by the researcher. The data from the interviews were coded and analyzed using HyperRESEARCH qualitative analysis software. In order to analyze the data in the observations, coding of the qualitative data procedure was employed. The teachers' poster presentations were evaluated by using the researcher-created rubric that has the criteria for each expected part of the poster presentation

To establish the credibility (internal validity) of the qualitative data prolonged engagement, peer debriefing, data triangulation, member checks, and time sampling strategies were employed. To establish the dependability (reliability) triangulation and peer examination strategies were conducted. Another science educator coded one of the science practices that included all teachers' answers in the interview. The inter-coder reliability was achieved as 100%. To establish the transferability of the study enough details were provided about each part of the research, as well as the use of purposive sampling method. Data triangulation and practice reflexivity was employed through keeping a research journal to establish the confirmability of the study (Anfara, Brown, & Mangione, 2002).

For the content validity of the survey, two professors were given the survey and asked to review it and express their thoughts about whether the content represents all the science practices. The survey was revised based on their recommendations. They subsequently agreed on all the items. To establish the internal validity of the survey it was pilot tested with the target population but with different teachers in the previous RET program in 2012. To determine the test-retest reliability of the survey, all the teachers completed the pre-survey two times before the RET program began.

The findings indicated that teachers' participation in the RET program helped them to improve their abilities to engage in science practices. The findings also suggest that they improved on most of the science practices, but they need more experience, knowledge, and abilities to engage in the specific practices where they had least improvements. In addition, the results suggest that teachers' understandings of most of the science practices did not show much improvement after they participated in the RET program. Some of the practices indicated minimal changes on some aspects, but the teachers still needed more clear understandings about them since their understandings would affect the way that they conceptualize the practices for their students when they prepare the students to engage in them.

The analysis also indicated that the teachers who actively engaged in the science practices, had productive discussions with the graduate student mentors and participated the quick lessons they gave, read the literature for their research, used new techniques and methods, and participated in the research group meetings improved more on the abilities of the science practices compared to the teachers who did not have the opportunity to participate in the practices because of the structure of their projects, had low interest, and received most of the information directly from the graduate students. In addition, this study found that the support in the research group and the engagement in the science practices are very important to improve teachers' understandings of the science practices. The practices that the teachers do not engage in and the research that is guided primarily by the mentors do not significantly help the teachers to understand the science practices.

Overall, the findings of this research suggest that teachers have naive understandings of science practices before they participate in an RET program because they do not have opportunities to learn what those practices mean. The findings also suggest that the teachers still have naive understandings after they participate in an RET program. This is a very important contribution to the literature, in that it is difficult for the teachers to teach those practices in their classrooms if they do not have complete and appropriate understandings of what those practices actually mean. Therefore, it is important that the science method courses and content courses for preservice teachers incorporate science practices within their curriculum. They should place an emphasis on teachers' experience in epistemic communities that allows them to engage in all the practices and focus on learning what each practice mean.

CHAPTER ONE:

INTRODUCTION

Statement of the Problem

According to the National Science Education Standards (National Research Council [NRC], 2000) and the Benchmarks for Science Literacy (American Association for the Advancement of Science [AAAS], 2010), scientific inquiry is one of the fundamental reform movements in science education in recent years. The development of scientific inquiry skills is one of the most important ways to educate scientifically literate and responsible citizens. Students should be able to formulate scientific hypotheses, produce explanations, design and conduct experiments, gather and analyze data, and communicate and reflect about the findings (NRC, 2000).

If teachers are going to be able to teach science and educate scientifically literate and responsible citizens, they should have the knowledge and skills to do science. In recent years, policy documents explicitly state that teachers should have a strong understanding of scientific inquiry to be better at teaching science (NRC, 2000; NSTA, 2003). According to the National Science Education Standards, “All teachers of science must have a strong, broad base of scientific knowledge extensive enough for them to understand the nature of scientific inquiry, its essential role in science, and how to use the skills and process of scientific inquiry” (NRC, 1996, p. 59).

In 2012, the NRC published a new science education framework, which started to use the term “practices,” instead of the term “skills,” to do scientific research. The reason for this change is a desire to stress that engaging in scientific inquiry requires coordination both of knowledge and skill simultaneously that is specific to each practice. The *Framework* provides the following list of science practices:

1) Asking questions;

2) Developing and using models;

3) Planning and carrying out investigations;

4) Analyzing and interpreting data;

5) Using mathematics and computational thinking;

6) Constructing explanations;

7) Engaging in argument from evidence;

8) Obtaining, evaluating, and communicating information (NRC, 2012, p. 42)

These practices are similar to the items found on survey instruments developed to measure the learning of scientific processes and skills (e.g., Kardash, 2000; Lopatto, 2004). All science teachers need some kind of support to improve their understanding about these science practices (NRC, 2012). One of the ways to provide authentic science experiences is to have teachers and students interact with research scientists (Feldman & Pirog, 2011). However, undergraduate courses do not prepare teachers how to teach scientific research (Roth, 1998), and most science teachers have never participated in scientific inquiry themselves (Blanchard, Southerland, & Granger, 2009; Roseler, Nguyen, Golden, & Southerland, 2012). This means many teachers are unable to teach their students according to the recommendations of the *Benchmarks for Science Literacy* (AAAS, 2010) or the *National Science Education Standards* (Alberts, 2000), and they possess very naive conceptions of inquiry in the classroom (Anderson, 2002; Blanchard, Southerland, & Granger, 2009; Roseler, Nguyen, Golden, & Southerland, 2012).

An important component of engaging teachers in scientific investigations is to have them participate in research experiences (NRC, 1996). Research Experiences for Teachers (RET) programs serve as a promising form of professional development to achieve this goal. These programs allow teachers to experience scientific inquiry (Blanchard, Southerland, & Granger, 2009; Roseler, Nguyen, Golden, & Southerland, 2012). The NSF funds RET programs via Directorates for Engineering (ENG) and Computer & Information Science & Engineering (CISE). It supports the participation of K-12 teachers who are in STEM fields. The main goal of RET programs is to engage teachers in engineering and scientific research, work collaboratively with the faculty and research community, and help them to translate their research experience into classroom teaching (NSF, 2012). In the RET programs faculty from engineering and computer science and the teachers work together in order to help the teachers to bring their experiences and knowledge into their classrooms. The teachers are provided the opportunities to work with researchers, faculty mentors, and research groups, which include undergraduate and graduate students. In these programs teachers work on research projects, participate in research seminars, engage in social and community activities, and participate in professional training sessions (NSF, 2012).

There is a dearth of research examining the RET programs and their effects on teachers' research skills. Most of the studies indicate that there is an increase in teachers' knowledge and skills to do research in the RET programs. There is a general agreement that RET programs are good for teachers for several reasons (Brown & Malear, 2007; Pop, Dixon, Grove, 2010; Raphael, Tobias, Greenberg, 1999; Westerlund et al., 2002). Some of the studies indicate that there is an increase in teachers' knowledge and skills to do research in the RET programs (Brown & Malear, 2007; Feldman, Ozalp & Alshehri, 2013). Some of them indicate that RET programs help teachers to increase their content knowledge (Brown & Malear, 2007; Westerlund, Garcia, Koke, Taylor, Mason, 2002). Also, RET programs increase teachers' ability to communicate what scientists actually do (Raphael, Tobias & Greenberg, 1999) and their confidence about views of the importance of science research in the classroom (Klein 2009). The problem is that these results are based on teachers' self-reporting of their knowledge and skills. These studies ask teachers to self-report on their knowledge and skills about scientific research, but most do not delve into their understandings of scientific research and skills. Therefore, this does not give us an accurate picture about what they actually learned.

Science teachers need to have a good understanding of science practices (NRC 2012). RET programs are designed to provide opportunities for science teachers to become involved in engineering and computer science research and to help them translate their research experiences and new knowledge into classroom activities. However, the problem is that we do not know what teachers actually learn about science practices in the RET programs. Therefore, it is important to find out teachers' understandings of the science practices and how these understandings change after they participate in the RET program. This study addressed this problem and provided findings about science teachers' understandings about science practices before and after they participated in an environmental engineering RET program. In addition, teachers' abilities engaging in science practices were examined to provide a complete picture of the results. This research also determined the sources of the differences of teachers' changes in their understandings of science practices and their abilities engaging in science practices to provide more insightful results for the study.

Theoretical Framework

Apprenticeships

The theoretical framework of this study is the "apprenticeship model" developed by Lave and Wenger (1991). In this model, learning occurs as a result of working like an apprentice. In the learning process, the apprentice engages in legitimate peripheral participation in a community of practice. Legitimate peripheral participation refers to the relations between the apprentice and expert, and the activities, identities, and communities of knowledge and practice. In the community of practice, members are connected to each other by a mutual agreement in order to accomplish their shared goal which includes the procedure and rules of the work (Wenger, 1998).

There are three main characteristics of apprenticeships;

- Learning and practice of the apprentice occur simultaneously because the apprentice learns by practicing the tasks.
- The apprentice completes the tasks, which are divided into manageable parts by the expert. This helps the apprentice to improve his/her knowledge and skills required to complete the work.
- The apprentice performs the tasks in a way that is similar to the expert's procedure (Lave & Wenger, 1991). In the apprenticeship model the novice becomes an expert ''through the mechanism of acculturation into the world of the expert'' (Brown, Collins & Duguid, 1989, p. 466).

Research Groups

Feldman, Divoll, & Rogan-Klyve (2009) developed a model for how students learn to do research. In this model the education of the students occurs as part of an apprenticeship (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991; Wenger, 1998), which takes place in research groups (Knorr Cetina, 1999). Research groups are structured in two ways: *loosely organized* and *tightly organized* (Feldman, Divoll, & Rogan-Klyve, 2009; Feldman & Ozalp, 2012; Feldman, Ozalp, & Johnston, 2011). The center for action is the main difference between the two types of research groups. In Feldman, Divoll, & Rogan-Klyve's (2009) study, the laboratory was the center of the action for the tightly organized research groups. In the tight organization, although the professors played an important role in developing the groups and facilitating interactions among the students, the student-student interactions that took place on a continuing basis were more important. The centers of action in the loosely organized research groups were the professors. In this structure, student-student interactions are very few because students' connections to the group were through the professors. Therefore, they spent more time with the professors rather than with the other students in the group (Feldman, Divoll, & Rogan-Klyve, 2009).

Participants have three different roles in the research groups: Novice researcher, proficient technician, and knowledge producer. *Novice researchers* have little or no experience with scientific research. They can develop the skills to help maintain the laboratory and collect data but are not expected to analyze it or to produce new knowledge. *Novice researchers* have a lack of laboratory or research skills, such as the ability to formulate research questions, and they have problems with drawing defensible conclusions from data. *Proficient technicians* develop the skills needed to collect and analyze data and report results of their research because they are longer-term members of the groups. They possess the research skills that allow them to do what is necessary for the research. They may not be able to formulate research questions, but they can apply the methods they have learned to new situations. Therefore, proficient technicians have the knowledge and skills to become skilled practitioners in their field. *Knowledge producers* have the abilities to formulate research questions, to produce new knowledge, and add to the research literature. Members of the groups can develop from novice researcher to proficient technician, to knowledge producer. The development of students along the continuum of roles is facilitated by the professor and other students (Feldman, Divoll, & Rogan-Klyve, 2009; Feldman, Ozalp, & Johnston, 2011; Feldman & Ozalp, 2012).

Communities of Practice and Epistemic Communities

Research groups can be organized in different ways, but they have the characteristics of both *communities of practice* and *epistemic communities* (Feldman, Divoll, & Rogan-Klyve, 2013). The concept of apprenticeship is used as legitimate peripheral participation in a community of practice (Feldman, Divoll, & Rogan-Klyve, 2009), which is related to situated learning of the skills and knowledge needed to do science (Lave & Wenger, 1991). Communities of practice have the characteristics of mutual engagement, joint enterprise, and a shared repertoire. The members are connected to each other by a mutual negotiation and engagement in order to accomplish their shared goal, which includes the repertoire and rules of the work (Wenger, 1998). In a community of practice people aim to accomplish and complete a product.

Research groups also aim to produce new knowledge. Therefore, they also have the characteristics of the epistemic community. In epistemic communities a group of people who have the required knowledge and skills come together and are mutually engaged in order to create and produce new knowledge. In short, in the community of practice the main goal is to complete a product, and in the epistemic community the main goal is to create new knowledge (Knorr Cetina, 1999).

The communities of practice, epistemic communities, and the participants are shown in Figure 1 (Feldman, Divoll, & Kyle, 2013, p.239). The research group is represented by the largest oval. The left side in the largest oval represents the features of the community of practice (COP), and the right side represents the features of the epistemic community (EC). The dashed line means there are no certain boundaries between epistemic community and community of practice. The research group shows the characteristics of both COPs and ECs. Participants may have different characteristics and show the characteristics of COP or ECs or both. In this example, the novice researcher entered the research group and left rather quickly with no expectation as being a full participant in the group (Feldman, Divoll, & Kyle, 2013).

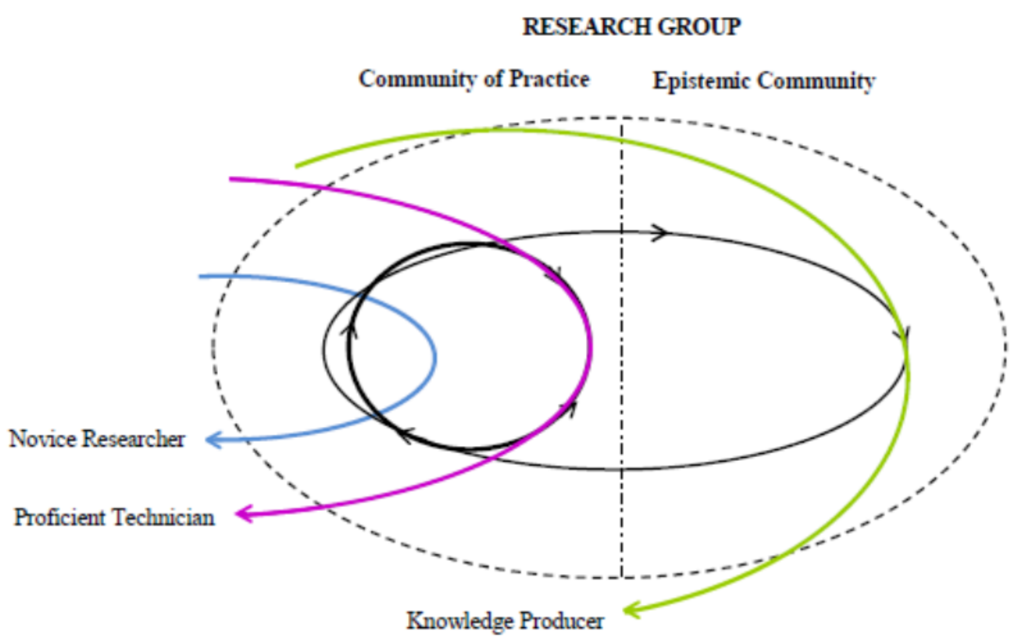

Figure 1. Communities of practice and Epistemic Community (Feldman, Divoll, & Kyle, 2013, p.239)

If the member of the group gains methodological proficiency or limited growth of intellectual proficiency this means that he/she leaves the group as a proficient technician. If the member of the group is involved as a full participant of both the COP and EC, this means that this person indicates the growth of both methodological and intellectual proficiencies. Therefore, she/he gains the knowledge and skills needed to participate in the epistemic community of research as a knowledge producer (Feldman, Divoll, & Kyle, 2013).

Feldman, Divoll, & Kyle (2013) conducted a study to find out how people learn to be a scientist while participating in a research group. The results indicated that one of the students entered the research and left rather quickly with no expectation that he would ever be a full participant in the group. This student experienced it primarily as a COP and gained only methodological proficiency, and so he left the group as a novice researcher. The other student had the possibility of becoming a full participant in the group. She was mostly involved with methodological aspects of research, but she indicated the limited growth of her intellectual proficiency and left the group as a proficient technician. Another student was a full participant of both the COP and EC aspects of the research group. As a result of participating in COP and EC, she indicated the growth of both her methodological and intellectual proficiencies and left the group as a knowledge producer. Methodological proficiency means having the ability to engage in specific techniques, using major instruments and protocols, modifying techniques and developing new ones, transferring established techniques to novel situations, exhibiting familiarity with research and research methods, and using published methodologies and innovating new ones (Feldman, Divoll, & Rogan-Klyve, 2009). Intellectual proficiency means having the ability to be clear about the research; to see and be aware of the purpose of the research; to use published literature as a source for ideas and as a context for current research; to formulate and articulate research questions; to see the data and analysis as a part of the literature of the field; to produce defensible conclusions from the data; to contribute to the knowledge base by presenting the research at conferences; and to produce, disseminate, or defend new knowledge (Feldman, Divoll, & Rogan-Klyve, 2009).

In the case of RET programs, teachers participate in communities of practice in order to acquire the skills and knowledge to do research. This participation provides teachers with new knowledge and skills in their research area. Therefore, teachers' learning in the research groups and communities of practice occurs as in the apprenticeship model. Based on the structure of the relationship, their research group can be loosely or tightly organized. In these research groups, in order to accomplish their research projects they work as apprentices with experts, professors, and graduate students. At the end of the program, if they gain only methodological proficiency this means that they leave the group as a novice researcher. If they gain methodological proficiency but limited growth of intellectual proficiency, this means that they leave the group as a proficient technician. If they are involved as a full participant of both the COP and EC this means that they indicate the growth of both methodological and intellectual proficiencies. Therefore, this indicates that they gain the knowledge and skills needed to participate in the epistemic community of research as a knowledge producer. That said, it is unlikely that a teacher becomes a knowledge producer as a result of a short-term research experience like the RET program (Feldman, Divoll, & Kyle, 2013, 2009, 2013).

Rationale for the Study

According to the NRC (2012),

> Teaching science as envisioned by the framework requires that teachers have a strong understanding of the scientific ideas and practices they are expected to teach, including an appreciation of how scientists collaborate to develop new theories, models, and explanations of natural phenomena (NRC, 2012, p.256).

Unfortunately, college-level science courses that are designed to offer these science practices are rare (NRC, 2012). Therefore, if teachers are required to have the experience of science then they should have opportunities to engage in authentic research.

This study provided important results by finding out science teachers' understandings of science practices. Also, this research determined whether teachers' abilities engaging in science practices remain the same or improve. The findings of the study are very important to provide information to compare teachers' abilities and understandings and what is expected in the new science education framework. If the teachers are expected to know and teach those practices in their classrooms they should know what the science practices mean and how to engage in them. Therefore, the study uncovered important findings about teacher' understandings of those practices. This study also provided important results about the RET programs as they aim to provide meaningful research experiences and how they affect the teachers' understandings and abilities of the science practices.

In the literature, there are different studies about teachers' gains in the RET programs (Dixon & Wilke, 2007; Klein, 2009; Pop, Dixon & Grove, 2010; Feldman, Ozalp, and Alshehri; 2012; Schwartz, Westerlund, Garcia, and Taylor, 2010). What is missing in the literature is: 1) what teachers' understandings of science practices are, 2) how participating in RET programs affect teachers' understandings of science practices, and 3) what are the sources of different changes in teachers' understandings and abilities of science practices after they participate in the RET program.

This study is designed to find out these missing points in the literature and provided a more accurate picture of the RET programs in terms of their effects on teachers' abilities in engaging in science practices and their understandings of science practices. Also, the study attempted to find out the reasons why the amount of teacher change is different for different teachers.

Purpose of the Study

The purpose of this study was to discover science teachers' understandings of the science practices before and after they participated in an environmental engineering RET program and to identify how teachers' participation in the RET program affects their ability to engage in these science practices. The study also identified some of the sources of differences in the science teachers' change in their understandings of science practices and abilities to engage in science practices.

Research Questions

Based on the purposes of the study, environmental engineering RET teachers' understandings about science practices before and after participating in an environmental engineering RET program were examined. The teachers worked on different research projects with professors and graduate students from environmental engineering and public health programs. Therefore, it was also interesting to find out the differences of teachers' change engaging in each of the science practices. In addition to that, finding out the sources of the differences in the teachers' change in understandings and abilities to engage in science practices completed the big picture of the study.

The research questions of this study were;

1. How does the participation in the RET program affect science teachers' ability to engage in science practices?

2. How does science teachers' participation in an environmental engineering RET program affect their understandings of science practices?

3. What are the sources of differences in RET teachers' change in their understandings of science practices and ability to engage in science practices?

Significance of the Study

This study provided significant findings to better understand science teachers' experiences in the RET programs and their ideas about science practices. The NRC (2012) requires that teachers have a strong understanding of the scientific ideas and practices they are expected to teach. This study produced important results in terms of finding out what science teachers think about science practices that are required to do inquiry. This provided important information about the picture of science teachers' ideas about doing science. Also, learning how RET programs affect teachers' understandings of the practices provided an accurate picture of the effects of RET programs on teachers' understandings of doing science.

The study also examined the sources of the differences in the RET teachers' change in their understanding of science practices and ability to engage in them. This was important to see the reasons that affect different amounts of changes in different teachers. Therefore, the results can guide RET program developers in order to create more effective RETs.

Definition of Terms

1. Science Practices: The first dimension of the new Framework for K-12 Science Education (NRC, 2012) that integrates the knowledge and abilities needed to engage in scientific inquiry. The practices are asking questions; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations; engaging in argument from evidence; and obtaining, evaluating, and communicating information (NRC, 2012).

2. RET program: Research Experience for Teachers Programs. These programs provide the teachers with well-structured research, education, and professional development experience by working with researchers, faculty mentors, and research groups which include undergraduate and graduate students (NSF, 2012). In these programs, teachers work on research projects and participate in research seminars, social and community activities, and professional training sessions.

3. Mentor: in this study, the graduate students who worked with and helped the science teachers in the RET program research projects.

4. Methodological proficiency: It means having the ability to engage in specific techniques, using major instruments and protocols, modifying techniques and developing new ones, transferring established techniques to novel situations, exhibiting familiarity with research and research methods, and using published methodologies and innovating new ones (Feldman, Divoll, & Rogan-Klyve, 2009).

5. Intellectual proficiency: It means having the ability to be clear about the research, to see and be aware of the purpose of the research; to use published literature as a source for ideas and as a context for current research; to formulate and articulate research questions; to see the data and analysis as a part of the literature of the field; to produce defensible conclusions from the data; to contribute to the knowledge base by presenting the research at conferences; and to produce, disseminate, or defend new knowledge (Feldman, Divoll, & Rogan-Klyve, 2009).

6. Communities of practice: Communities of practice have the characteristics of mutual engagement, joint enterprise, and a shared repertoire. The members are connected to each other by a mutual negotiation and engagement (Lave and Wenger, 1991; Wenger, 1998). In community of practice, people aim to accomplish and complete a product.

7. Epistemic community: In epistemic community, people are mutually engaged in order to create and produce new knowledge. Since the purpose of the epistemic communities is to create knowledge, the members of the community must be able to warrant the new knowledge to convince other people who are not the members of the research group (Knorr Cetina, 1999).

8. Mixed methods research: Mixed methods research is the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study (Johnson & Onwuegbuzie, 2004, p.17).

Summary

The purpose of this mixed methods study was to find out science teachers' understanding of science practices in an environmental engineering program. The study also focused on how participating in the RET program affects teachers' abilities engaging in science practices. In order to understand the big picture of the findings, the sources of the difference in teachers' understandings and abilities were examined. The teachers participated in a six-week environmental RET program and worked with the professors and graduate students from environmental engineering and public health.

The research questions of this study were:

1. How does the participation in the RET program affect science teachers' ability to engage in science practices?

2.How does science teachers' participation in an environmental engineering RET program affect their understandings of science practices?

3. What are the sources of differences in RET teachers' change in their understandings of science practices and ability to engage in science practices?

Researcher

I graduated as an honor student from the Chemistry Education Program in 2006 from Marmara University, located in Istanbul, Turkey. During my undergraduate education, I worked as a student assistant with research assistants in an analytical chemistry laboratory for three years, which was my first experience in teaching. For this position, the student assistants were selected from among the students who have high achievement and also who have the ability to be a teaching assistant. I was very excited working with the undergraduate students in the lab because my first purpose in academia was being a faculty professor. I believe that I learned a lot as an educator how to communicate with the students and deal with their problems. In this laboratory, I prepared samples which were required to be analyzed by the chemistry and chemistry education students. I taught them how to analyze the samples and helped them during their analysis. I think this full three-year experience prepared me as a college teacher. The analytical laboratory hours were always long, but I performed this job very enthusiastically because I liked to work with the college students in the university setting.

After graduation, I started to work as a chemistry teacher, and I was accepted to the Chemistry Education Master Degree Program in the same university. I worked as a chemistry teacher at the high school level for three years. This was my first professional teaching experience after my internship, and I had different experiences with high school students. In Turkey, the students have to take a national exam at the end of the 12^{th} grade. Since they have only one chance to take the exam each year, in each class the primary focus was to prepare the students for the exam. During these years, I did not have an opportunity to work with the students in the laboratories because we had to complete required practice questions for the exam every day. I was always thinking that science cannot actually be learned only solving the multiple choice questions because I believe that science can be learned more effectively by engaging in real research activities with more hands-on experiences.

After two years of teaching, I graduated with my master's degree, having good experiences in the field of research. My research topic was diagnostic assessment of middle and high school students' misconceptions about the particulate nature of matter. In my master's study, I worked with approximately 800 students. Finding out students' misconceptions was really an interesting experience for me because I think if students have misconceptions their future scientific knowledge potentially will have naïve conceptions. This research provided me with an interesting two years in the master's program and strengthened my desire to be a college professor and pursue my doctorate degree in science education.

I decided to complete my PhD degree at the University of South Florida, and I was accepted into the Science Education program in 2010. I think coming to the US was the most important change in my life, both personally and professionally. My purpose for pursuing a PhD degree in science education at the University of South Florida is because I want to have an incredibly strong knowledge about science education and learn as much as I can to be a successful professor in academia.

As an international student, the first year of my PhD education was kind of an orientation process to the culture, language, and education system. I think this is the most important experience I have had in my life until now, because starting to live in a different country is both challenging and also exciting. I have had to get used to the things which are different to me, and it is also exciting to meet different people and learn about their culture.

From the first semester of my PhD education, I started to work with my advisor as a program evaluator in a project about Research Experience for Undergraduate students. This project was very much related to my interests, and it helped me to find out about undergraduate students' research experiences in environmental engineering laboratories with the graduate students and the professors. I believe that I learned a lot about how to do research from my advisor, and I improved my knowledge and skills about doing research. While evaluating students' research experiences I feel that my knowledge and skills also increased in each step of the research. Therefore, I believe that the experience I had in the REU study has helped me a lot in my dissertation study.

I also worked as a research assistant in the Coalition for Science Literacy department, and I conducted literature reviews on different topics. The experience I had in this program improved my ability to review the literature. My other research assistantship was in the environmental engineering program in the evaluation of the S-STEM project. During this three-year assistantship, I learned a lot in terms of how to do research because I created data collection instruments to evaluate the program. The data collection and analysis experience I gained in this project was very beneficial for me in terms of doing research.

The experiences I had working in different projects are very valuable for me because they helped me to conduct my dissertation study. In these projects I learned everything including preparation of data collection instruments, data collection, analysis and interpretation, writing the research papers and reports, and oral presentations. My advisor's guidance helped me a lot in learning how to do research. My interest was inquiry when I began the PhD program, but it was very broad and (as expected) I had to narrow it down in order to apply it in my research. I think the experiences I had in these projects with my advisor helped me to decide what I wanted to study in my research. The primary purpose of my dissertation study was to find out science teachers' understandings of science practices before and after they participate in the environmental engineering RET program. Teachers' ability to engage in science practices and the sources of the differences in teacher changes were also the focus of the study.

In this study I had the role of the researcher and participant observer. As a researcher, I administered the surveys and interviews, and also I reviewed all the documents such as the poster presentations. As a participant observer, I observed the teachers in the laboratories while they did their research. And at the end of the research I reported all the findings by establishing trustworthiness, validity, and reliability.

CHAPTER TWO:

LITERATURE REVIEW

What is Scientific Inquiry?

According to the NRC (1996),

"Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communcating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. Students will engage in selected aspects of inquiry as they learn the scientific way of knowing the natural world, but they also should develop the capacity to conduct complete inquiries (NRC, 1996, p.23)."

Scientific inquiry is a more detailed process than making careful observations and then organizing them. It is more flexible than the steps in the scientific method and much more than just doing experiments, and not restricted to laboratories. Scientific inquiry involves more imagination, inventiveness, strict logic, and empirical evidence. If students participate in good scientific research processes they can come away with an accurate picture of scientific inquiry. To manage the traditional school science experiment laboratory that does not do the real science should be revised. In these school laboratories the process of the research including the research questions, methods, data collection, and data organization are all decided by the teacher. The repetition of the experiments is not possible, the results are not criticized and the correct answer is known ahead of time (AAAS, 2010).

In short, scientific inquiry is the combination of different ways in which scientists study the natural world and explain the relationships and reasons between different natural phenomena based on the results of their work. Scientific inquiry includes several activities which allow students to develop scientific knowledge and how scientists study the natural world (NRC, 2000).

Why is Scientific Inquiry Important to Teach and Learn Science?

Inquiry in education is important because if it is constructed in an appropriate way it motivates students by placing them in a puzzle which requires them to involve risk taking process. It includes both a state of a skill that must be learned from experience and a state of mind which requires having the curiosity to ask "why" and "how" questions. Young children are naturally curious, but if their questions are dismissed by adults, children can lose the curiosity that they possessed and develop into passive adults who do not question. Therefore, it is very important to answer children's questions in order to bring alive their curiosity (Alberts, 2000).

Scientific inquiry is a method which allows scientists to understand the natural world (NSTA, 2004). Within a classroom inquiry, it is an active learning process in which students act like scientists by collecting and analyzing data (Bell, Smetana, & Binns, 2005). Students have a connection to their environment, and they interact with it by asking questions and seeking ways to answer those questions. Through inquiry experiences it is easier to understand science, and it also helps to enhance students' ideas. Therefore, scientific inquiry is an important way of understanding science content. It helps students to learn the abilities about how to ask questions and use evidences to answer them. In this process, students also learn how to conduct an investigation and collect data, develop an explanation, and communicate their conclusions through a variety of scientific procedures (NSTA, 2004).

Schools are responsible to develop the state of mind needed to be an inquiring adult. Children can use the methods of inquiry to find answers for their questions if we maintain their initial curiosity about the world. One of the ways to achieve this goal is to provide them opportunities to obtain the skills needed to do research. The schools should conduct a curriculum that begins in kindergarten and increases in difficulty. Rather than the memorization of scientific knowledge, the curriculum should focus on student and class inquiry. Students should be presented with different types of inquiries, and they should acquire the skills of inquiry so they will be more proficient in questioning the world around them. In this way, school becomes a place for students where they recognize that they are learning skills that they can use outside of school (Alberts, 2000).

What are the Research Skills Needed to Do Scientific Research?

We aim for students to acquire some of the reasoning and procedural skills of scientists and an understanding of the nature of science. When students do scientific inquiry we want them to struggle with possible answers to problems and design experiments that test some of their ideas. Bybee (2000) offers three main components of scientific inquiry. Inquiry is content which includes students' understanding about scientific inquiry, the required abilities to perform it, and the teaching strategies and the processes of learning related to it. Bybee (2000) explains that to do scientific inquiry students should be able to:

- Identify questions and concepts that guide scientific investigations.
- Design and conduct scientific investigations.
- Use technology and mathematics.

- Formulate and revise scientific explanations and models using logic and evidence.
- Recognize and analyze alternative explanations and models.
- Communicate and defend a scientific argument (Bybee, 2000, p.33).

In terms of students' understandings about scientific inquiry students should understand (Bybee , 2000):

- Conceptual principles and knowledge that guide scientific inquiries.
- Scientists conduct investigations for a variety of reasons including discovering new aspects of the natural world, explaining recently observed phenomena, testing conclusions of prior investigations, and making predictions of current theories.
- Scientists rely on technology to enhance the gathering and manipulation of data.
- Mathematics is essential in scientific inquiry.
- Scientific explanations must adhere to criteria, such as logical consistency, rules of evidence open to questioning and be based on historical and current knowledge.
- Results of scientific inquiry—new knowledge and methods—emerge from different types of investigations and public communications among scientists (Bybee, 2000, pp.34-35).

Some researchers developed surveys to find out the gains and research skills of the teachers who participated in RET programs. They are presented below.

Research Skills Surveys

Lopatto (2004) developed and conducted a Survey of Undergraduate Research Experiences (SURE). It consisted of 44 items, including demographic variables, learning gains, and evaluation of aspects of summer research programs. There are 20 items regarding learning gains, and they were suggested by previous survey research. The learning gains items are understanding of the research process, ability to integrate theory and practice, readiness for more demanding research, understanding primary literature, understanding how scientists work on real problems, assertions require supporting evidence, learning lab techniques, understanding science, tolerance for obstacles, understanding how scientists think, learning to work independently, self-confidence, skill in the interpretation of results, clarification of a career path, ability to analyze data, skill in oral presentation, understanding how knowledge is constructed, and skill in science writing.

Lopatto (2004) stressed that there is a gain in students' understanding of the research process because the survey results indicated an increase in this item. However, there is not any evidence about how this learning gain was measured. First of all, participants self-reported their gains, but we do not know what their understanding about each gain is.

In this survey Lopatto (2004) includes the definition of each item. Participants read the definition and then they score their skill. However, this is not a sufficient answer because merely reading the definition of a term does not mean people understand it, or they have the same meaning in their minds because people can memorize the term without understanding it. The definition is provided by the author of the survey so we do not know what the teachers understand and, most importantly, we do not have any information about their understandings of the meanings of these research gains. Therefore, learning participants' real understandings about the learning gains is very important in order to understand their thinking concerning them.

In 2006, SRI International published a major study of undergraduate research opportunities. This study was commissioned by the NSF and surveyed undergraduates, graduate students, post-doctoral fellows, and faculty (Russell, 2006). The survey items are related to confidence in their research skills generally, skills/abilities in working independently, understanding of how to deal with setbacks and negative results, skills/abilities in preparing written research reports, papers, or posters, understanding of how to conduct a research project, understanding of how to plan a research project, skills/abilities in delivering oral research presentations, understanding of how to formulate a research question, skills/abilities in working collaboratively with others and awareness of ethical issues in conducting research.

The SRI study, like Kardash's (2000) and Lopatto's (2004), relied on participant self-reporting. In the Lopatto (2004) survey they gathered data about students' perceptions of what they learned during the UREs and what activities they experienced, but the items are not specific for the research skills only and did not provide teachers' understandings about them.

Kardash (2000) also developed a research skills survey. The survey items include how teachers make observations and collect data, analyze numerical data, orally communicate the results of the research, understand the importance of "controls" in research, reformulate the original hypothesis, write a scientific report of the research, interpret data by relating results to the original hypothesis, identify a specific question for investigation in the research area, relate results to the "bigger picture," think independently about the research area, design an experiment or theoretical test of the hypothesis and make use of the primary scientific research literature in the research area.

The items in Kardash's (2000) survey are more useful than the ones in the other surveys because first of all, the items are only about research skills, but Lopatto's (2004) items are the overall gains in the RET program. Also, the items in this survey cover all the important skills which are required to do research. In order to determine the research skills that will be assessed in the survey, Kardash (2000) conducted a literature review calling for curricular reform in undergraduate science, and she also reviewed published reports that have data of the UREs at a variety of institutions. Most of these reports are published in *Council for Undergraduate Research Quarterly*, which has the aim of showing how UREs should be assessed and evaluated (Consortium for Policy Research in Education, 1995). During her study six URE mentors from the physical and life sciences at the university evaluated the quality of posters presented by undergraduates. She also asked these professors to list the specific criteria they used in making their evaluations. At first, she examined anticipated learning outcomes for UREs which emerged from these three data sources, and then she developed preliminary categories and the research skills list. Six faculty mentors who had rated the posters and five other science faculty members who served as URE mentors discussed the categories in order to reach consensus about the research skills that students were expected to acquire during the URE. Mentors reviewed 14 research skills to identify the most important and critical skills. This survey used a 5-point Likert type scale survey and items ranged from 1 *(not at all)* to 5 *(a great deal)*. For students and mentors internal consistency and item correlations (alpha) were calculated separately. Based on ratings from the 57 research students the internal consistency was 0.90 and item-total correlations ranged from 0.49 to 0.76. The internal consistency based on the ratings obtained from 24 faculty mentors was 0.96, with item-total correlations ranging from 0.78 to 0.88. Kardash's (2000) survey does not include the definitions of the items (research skills) since merely reading a term does not reflect teachers' understandings about it, and because people may memorize a term without understanding it. Also, Kardash's (2000) survey depends on self-reporting. This means that we may not know teachers' real views about the research skills. Considering all these factors, it is more reasonable to find out teachers' understandings about each research skill in Kardash's (2000) survey.

Science Practices

The National Research Council published a new Framework for science education in 2012 (NRC, 2012). This Framework articulates the committee's vision of the scope and nature of K-12 education in science, engineering, and technology needed for the 21st century. It describes all aspects of science education that all students should be familiar with by the end of high school, including the major practices, crosscutting concepts, and disciplinary core ideas. The Framework is designed to help students to engage in scientific and engineering practices and apply crosscutting concepts in related fields.

The science practices described in this Framework are;

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

The NRC (2012) states that by the end of the 12th grade, all students (not only the ones who pursue a career in science or engineering) should have gained sufficient knowledge of the practices, crosscutting concepts, and core ideas of science and engineering in order to understand how scientific knowledge develops; and which approaches are used to investigate and provide explanations about the world. These activities are important for students to engage in public discussions on science-related issues, to be critical consumers of scientific information related to their everyday lives, and to continue to learn about science throughout their lives.

The Relationships between Science Practices and Research Skills

In this study, teachers' understandings of science practices were examined. The research skills in the Kardash (2000) survey are closely related to the science practices, as well as being more detailed (Figure 2). For example, in general one science practice is closely related to multiple research skills.

"Identify a specific question for investigation" is directly related to the *asking questions practice* because the purpose of both of them is to formulate empirically answerable questions about phenomena under consideration. Also, both of them should be produced by considering what is already known and what questions have yet to be satisfactorily answered. Therefore, "identify a specific question for investigation" research skill can be used instead of *asking questions* science practice.

The NRC (2012) Framework cites Nercessian (2008) to explain how scientists use the models. "Scientists use models to represent their current understanding of a system (or parts of a system) under study, to aid in the development of questions and explanations, and to communicate ideas to others" (p.57). From these explanations we can say that to identify a specific question for investigation in the research area is related to this science practice because scientists use the models when they develop questions. Also, scientists use models to develop explanations which are directly related to formulate a research hypothesis because hypothesis is a kind of explanation which is developed based on a model or a theory. "Write a scientific report" and "orally communicate the results of the research" skills are also connected to

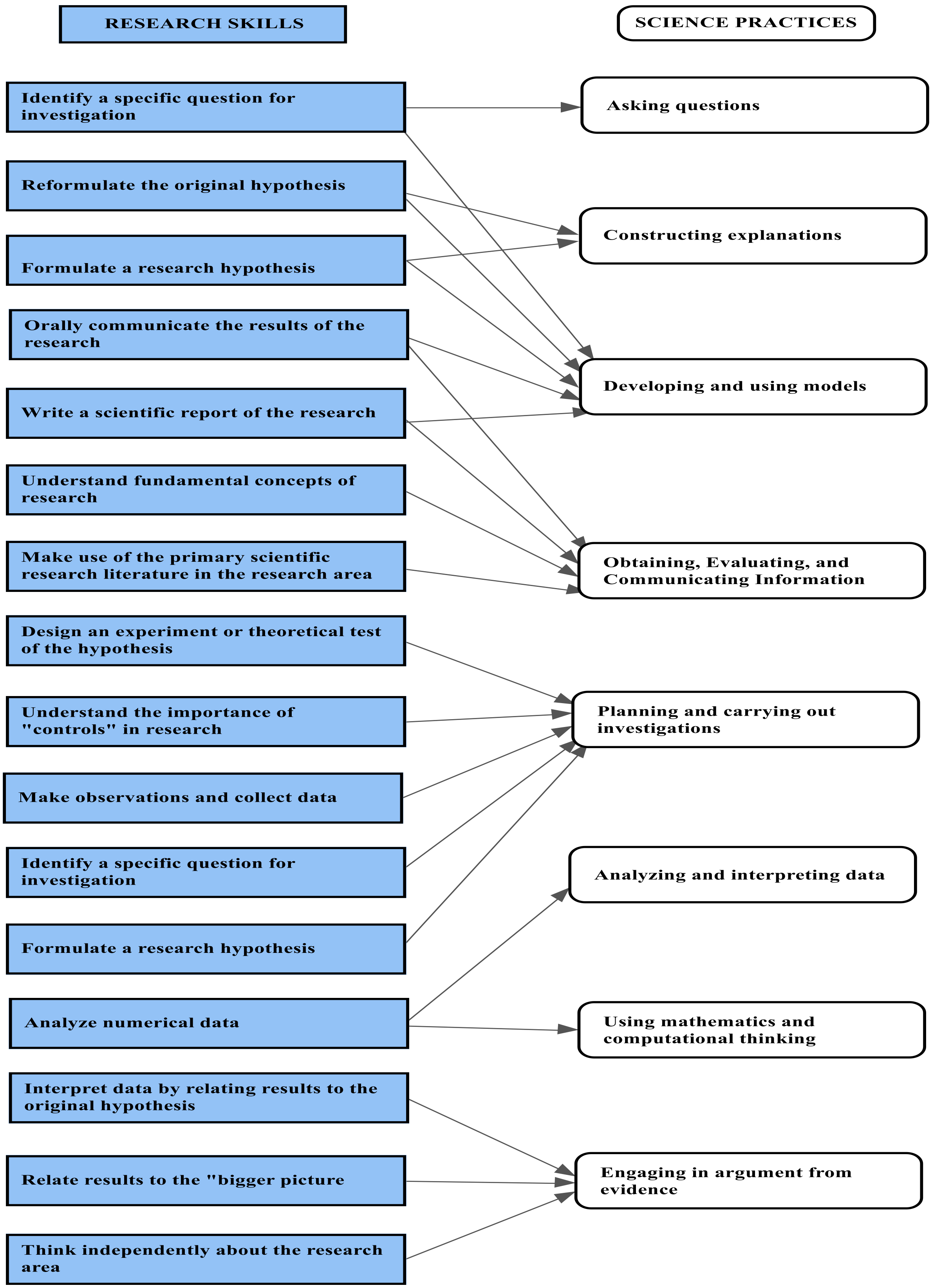

Figure 2. The relationships between science practices and research skills

developing and using scientific models science practice because these are the ways to communicate the ideas to the other people.

"Design an experiment, make observations and collect data, understand the importance of controls" research skills are directly related to the *planning and carrying out investigations* practice. An experiment is a kind of investigation. Therefore, to "design an experiment" is directly related to the planning and investigation. Scientists ask questions, frame a hypothesis, make observations, and collect data in the investigation process in order to develop, test, and revise the theories and explanations (NRC (2012). Carrying out an investigation begins with identifying the variables and controls of the study (NRC, 2012). Therefore, understanding the importance of controls is included in planning an investigation practice. For these reasons "design an experiment; identify a question for investigation, formulate a research hypothesis, reformulate the original hypothesis, understand the importance of controls and make observations and collect data" research skills can be combined to explain the *planning and carrying out investigation* science practice.

Analyze and interpret data science practice includes both qualitative and quantitative data analysis procedures. Therefore, the "analyze numerical data" research skill is directly related to the practice of *analyze and interpret data* science practice. The NRC (2012) states that *using mathematics and computational thinking* science practice helps scientists to search for patterns and identify relationships between the variables and significant features of the scientific phenomena. Mathematics enables ideas to be expressed in a precise form and enables the identification of new ideas about the physical world. In order to analyze numerical data, scientists use their mathematical and computational skills to see the relationships between the variables and explain the findings with numerical expressions. Therefore, the "analyze numerical data" research skill is also closely related to the *using mathematics and computational thinking* science practice. Also, "interpret data by relating results to the original hypothesis" research skill is directly related to this science practice because *analyze and interpret data* research skill obviously includes that.

About the *constructing explanations* science practice, the Framework states that "in science, the term 'hypothesis' is also used differently than it is in everyday language. A scientific hypothesis is neither a scientific theory nor a guess; it is a plausible explanation for an observed phenomenon that can predict what will happen in a given situation. A hypothesis is made based on existing theoretical understanding relevant to the situation and often also on a specific model for the system in question" (NRC, 2012, p.67). Based on this explanation we can say that a hypothesis is a kind of explanation. Therefore, formulate a research hypothesis and reformulate the original hypothesis research skills are directly related to constructing explanations science practice.

For engaging in argument from evidence science practice, the NRC (2012) states that scientists defend their explanations by offering evidence which is produced based on a set of data. It means that this practice requires considering the results of the research in order to explain or interpret the findings to explain the phenomena. In this way, they try to formulate their own understanding based on the evidence that they produced, in addition to findings offered by other studies. The purpose of this practice is to explain the ideas about phenomena, interpretation, or a solution based on the results of the study. Therefore, "interpreting data by relating results" skills are related to the *engaging in argument* science practice because both do the explanation and interpretation based on the results or findings of the research. The NRC (2012) states that an inductive generalization of existing "patterns" is a form of making an argument. Similarly, the “relate results to the bigger picture” skill requires seeing the general picture of the phenomena and placing the results into it. Therefore, if we assume that the “patterns” are the results of the study, relating these results to the bigger picture is a kind of effort of putting it in the general framework. Therefore, the “relating results to the bigger picture” skill is closely related to *engaging in argument practice*. Engaging in argument practice requires the scientists to understand their own ideas based on some findings and data. In this process, scientists think independently in order to compare their ideas and findings with the results in other studies. Therefore, the “think independently in the research area” skill can be included in the *engaging in argument* science practice.

For the *obtaining, evaluating and communicating the information* science practice, the NRC (2012) states that scientists need to have the ability to read and understand the literature, interpret and produce scientific reports, and communicate in written and spoken form. Therefore, this practice includes producing a literature review and also understanding what the literature says about the concepts in the research area. Understanding the concepts and what the literature says are also important because only reading the literature is not enough to complete a literature review. Therefore, “make use of the primary scientific literature” and “understanding the contemporary concepts” research skills are closely related to the *obtaining, evaluating the information* practice. Communicating science can be done orally in conferences, meetings, and presentations; it can be also accomplished through written documents such as reports, journals, books, and emails (NRC, 2012). Therefore, “write a scientific report” and “orally communicate the results of the research” skills are directly related to the *obtaining, evaluating and communicating the information* practice.

Research Experiences Programs

Research Experiences for Undergraduates (REU) Programs

Before explaining the RETs, it is important to present the literature about undergraduate research experiences, which includes REU programs, firstly because there is more research about REUs than RETs. And secondly, the structure of both REUs and RETs is similar, so it will help to see the structure, goals, and differences and to make connections between the outcomes of the REUs and RETs.

Description and objectives of the REU programs. For more than 20 years, the NSF has supported REU programs all over the U.S. The main goal of these programs is to provide a well-structured research and professional development experience to undergraduate students in different fields.

The NSF (2012) states that REU programs provide appropriate and valuable educational experiences for undergraduate students through participation in research. The objectives of these programs are to train student participants in the steps required for scientific research, to encourage student participants to pursue an advanced degree in their field, to establish a sustainable mechanism for broadening participation in academic research, to create a collaborative community for mentoring, and advising undergraduates in experiences that advance faculty research. REU programs provide opportunities for students to become involved in the scientific research process. In the REU programs, students have interactions with faculty and other research mentors, and they have opportunities to engage in different professional development activities (NSF, 2012). Generally, students in the REU programs engage in ongoing research projects or in projects that are designed for the REU program (NSF, 2012). They work in research laboratories with researchers and graduate students, typically over a period of six or ten weeks. Additionally, they participate in workshops, field trips, and oral and poster presentations.

Outcomes of the REU programs and undergraduate research experiences. In this section, the literature about the REU programs is discussed. The outcomes of the REU programs and undergraduate research experiences are presented in Table 1. Kardash (2000) conducted research to measure the outcomes of an URE program. Each week students worked 12 hour in the laboratories for a 32-week period in the 1997-98 academic years. Students attended several workshops focusing on career-related issues and they attended poster presentation. Kardash used a survey to assess students' self-perceptions of their abilities to perform particular skills related to doing scientific research after the program. Students reported that their abilities about orally communicating, observing and collecting data, relating the results to the "bigger" picture in the field, and understanding contemporary concepts in the field increased after participating in the program. Students rated some skills lower, including writing a research paper for publication, identifying a specific question for investigation, translating the question into a workable hypothesis, designing a theoretical test of the hypothesis, and reformulating the hypothesis based on one's experimental results. This result indicates that students rated the skills which require higher order thinking abilities lower than the ones which require less thinking. In order to write a research paper for publication, to identify a specific question for investigation and translate the question into workable hypothesis, students should have higher order thinking experiences.

Feldman & Ozalp (2012) reported the results of a two year study of a ten-week environmental engineering REU program. They found that the program improved students' research skills but not the ones needed to be independent researchers. Also, the results indicated that almost all their learning occurred as part of apprenticeship activities structured and facilitated by professors within the research groups. In addition, the organization of the research groups and the level of involvement of the professors in the education of the undergraduates affected how much they learned about doing research.

SRI International (2006) reported a study in which the authors surveyed 15,000 participants including undergraduates, graduate students, post-doctoral fellows, and faculty about undergraduate research opportunities (URO) (Russell, 2006). The SRI study is similar to Kardash's (2000) in terms of data collection strategy. Both of the studies used surveys about students' gains in the programs, with the results relying on participant self-reporting. The undergraduates completed a variety of activities in the program including "the collection and or analysis of data to answer a research question; input into or responsibility for decisions about next steps in the research process, and decisions about research techniques or materials; and oral presentations, posters, and written final reports" (Russell, 2006, pp. 14-16). The SRI study and Kardash's (2000) research also have similar outcomes. The results indicated that students' understanding of the research process and their confidence in their ability to do research improved, and URO also made positive effects on their awareness of academic career opportunities in the STEM disciplines. This study also reported the relationship between the results and the types of research activities. Authoring or co-authoring a journal paper, attending a professional or student conference, mentoring other students, and being given the opportunity to increase their independence as researchers were the most strongly related activities to the outcomes. Involvement in project decision-making, delivering oral presentations about one's research, and collecting and analyzing data to answer a research question were the most weakly-related activities (Russell 2006).

Table 1.

The citations, methods and results of the research experiences of undergraduates

Citation	Methods	Results
Kardash, C. M. (2009). Evaluation of an undergraduate research experience: perceptions of undergraduate interns and their faculty mentors. *Journal of Educational Psychology, 92*(1), 191-201.	• URE students worked 12 hr a week in their mentors' laboratories for a 32-week • Fifty-seven undergraduates science research interns • Research skills survey were used	• Students' skills about orally communicating, observing and collecting data, relating the results to the "bigger" picture in the field, and understanding contemporary concepts in the field increased • The skills of writing a research paper for publication, identifying a specific question for investigation, translating the question into a workable hypothesis, designing a theoretical test of the hypothesis, and reformulating the hypothesis based on one's experimental results decreased
Russell , S. H. (2006). Evaluation Of NSF Support For Undergraduate Research Opportunities: Draft Synthesis Report. Menlo Park, CA: SRI International.	• Different URO programs in US • 15,000 undergraduates, graduate students, post-doctoral fellows, and faculty • Survey were used	• Students' understanding of the research process and their confidence in their ability to do research improved, • Authoring or co-authoring a journal paper, attending a professional, mentoring other students, and being given the opportunity to increase their independence as researchers were the most strongly related activities to the outcomes.
Seymour, E., Hunter, A., Laursen S. L., & Deantoni, T. (2004). Establishing the Benefits of Research Experiences for Undergraduates in the Sciences: First Findings from a Three-Year Study. *Science Education, 88,* 493– 534.	• Summer REU program • 76 students from liberal arts colleges • Interviews were conducted	• Students increased in communication skills, personal/professional gains, thinking and working like a scientist. • Presenting posters or papers at conferences, or writing formal and scientific reports were the benefits that were achieved by few students. • REU had clarified, refined, or confirmed students' pre-existing choice of career directions or increased their interests in research and academic work.
Hunter, A. B., Laursen, S. L., & Seymour, E. (2006). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education, 91,* 36-74.	• Liberal arts UR program • More than 100 undergraduates • The total of 367 student and faculty interviews	• Few students grew in their ability to identify, frame, and refine new research questions, professional writing, and research design • Some students reported gains in the ability to successfully apply critical thinking and problem-solving skills to the work at hand, including the capacity to analyze data in relation to scientific concepts and theories framing research
Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *Life Sciences Education, 6*, 297–306.	• The original SURE was completed by 1135 undergraduates representing 41 universities • In the second year, 2021 undergraduates representing 66 institutions completed the survey.	• There is a high consistency between the follow-up survey and the SURE survey. • The students who discontinued postgraduate education also reported significantly lower gains. • The lowest gains: "readiness for more demanding research" and "understanding how scientists work on real problems" highly, while "learning ethical conduct," "skill in science writing" and "skill in oral presentation," were the lowest rated gains.

Table 1 *(Continued)*

Feldman, A., & Ozalp, D. (2012). Learning to do research in a research experience for undergraduates (REU) program. Paper presented at National Association Research in Science Teaching (NARST) Conference, Indianapolis, IN.	• Ten weeks environmental engineering REU program • Twenty one undergraduate students • Surveys, interviews and observations, document analysis were conducted	• The students learned research skills, but not the ones needed to be independent researchers. • Almost all their learning occurred as part of apprenticeship activities structured and facilitated by professors within the research groups. • The ways the research groups were organized and the level of involvement of the professors in the education of the undergraduates affected how much they learned about doing research.
Ellington, R., Wachira, J., & Nkwanta, A. (2010). RNA secondary structure prediction by using discrete mathematics: An interdisciplinary research experience for undergraduate students. *Life Sciences Education, 9*, 348–356.	• Six weeks molecular biology and discrete mathematics REU program • Five upper-level undergraduate students • Informal observations, informal interviews, student attendance	• The students gained knowledge and skills in bioinformatics, and an awareness of the applications of discrete mathematics to biological research problems. • Students also demonstrated positive attitudes toward interdisciplinary content and research. In addition, many students developed their own research that extended the work of the project and presented their work at several conferences.
Qu, Z. (2004). Design and successful implementation of an NSF research experiences for undergraduates site in semiconductor manufacturing. *International Journal of Engineering Education, 20*(4), 552-560.	• Twelve weeks semiconductor manufacturing REU program • Ten undergraduate students • Student final defense of their research was evaluated by faculty	• REU students are more likely to choose a research topic that is a part of an ongoing research project that enables them to talk to graduate students and engineers/scientists convinces them of its practical importance. • They could not write the reports so additional time was given to them. However, after the completion of REU projects still more work was required for publications.
Zydney, A. L., Bennett, J, S., Shadid, A., & Bauer, K. W. (2002). Faculty Perspectives Regarding the Undergraduate Research Experience in Science and Engineering. *Journal of Engineering Education. July, 291-297.*	• The perceptions of 155 science and engineering faculty were examined • Faculty Survey on Undergraduate Research was conducted	• The faculty who supervised undergraduates for two or more years believed the impact in cognitive and personal skills, the skills of developing intellectual curiosity, thinking logically about complex materials, synthesizing and using information from diverse sources, and understanding ethical implications was significantly greater than those respondents who typically supervised undergraduate researchers for one year or less.
Delatte, N. (2004). Undergraduate summer research in structural engineering. *Journal of Professional Issues in Engineering Education and Practice, 130*, 37-43.	• Nine weeks REU in structural engineering • Thirty three undergraduate students • Survey was used	• Although some students had planned to continue on to graduate school, some decided not to, and some of them had not planned to continue but changed their minds. • The REU program did not encourage more students to go to graduate school, but it helped the students to identify their
Yarnall, B. & Neff, R. (2007). Teaching global change in local places: The HERO research experiences for undergraduates program. *Journal of Geography in Higher Education, 31*(3), 413–426.	• Eight weeks REU program in geography department • Each year 12–16 students attended • Student evaluation survey	• Students rated their research process activities such as interviewing, coding processes, video conferences, codex, concept mapping, and the writing of final papers highly positive.

Seymour, Hunter, Laursen and Deantoni (2004) reported on an undergraduate research experiences program, which included 76 students from liberal arts colleges. There were different types of benefits of the program for the students: personal/professional gains, thinking and working like a scientist, gains in various skills, clarification/confirmation of career plans, enhanced career/graduate school preparation, shifts in attitudes to learning, and working as a researcher. They also found that some expected benefits were not seen in high percentages. For instance, presenting posters or papers at conferences, or writing formal and scientific reports were benefits that were achieved by few students. Communication skills were the most cited gains, with students' ability to explain, present, discuss, and defend their work to peers and the professionals as the most reported gains about communication. The results indicated that REUs did not prompt rising seniors to choose particular careers, but it had clarified or confirmed students' choice of career decisions or increased their interests in research and academic work.

Hunter, Laursen and Seymour (2006) conducted a summer undergraduate research (UR) experiences program and reported their results. According to observations offered by faculty and students, few students improved their ability to identify and refine research questions or to select or develop alternative experimental designs for their study. The faculty and students referenced gains in application of critical thinking and problem-solving skills, including data analysis. While a large percentage (46%) of students reported gains in understanding how science research is done and in applying their critical thinking and problem-solving skills to research, nine percent of them reported gains in their ability to develop a research question and design, while professional writing skills were at much lower levels (8% and 7%).

These findings are also similar to Kardash's (2000) outcomes as she found only limited gains in higher-order skills, particularly the skills relating to how to generate and frame research problems so they can be approached scientifically. Her conclusions reflect the outcomes of this study. Both studies indicated that although undergraduate research experiences are successful in improving some kind of basic scientific research skills, they are limited in gains to higher-order inquiry skills that are important and fundamental for critical scientific thinking.

In general, these studies conducted surveys in order to find out the effects of the URE programs on students' research skills and their decisions about going to graduate school. Like Kardash (2000) and SRI International (2006), Lopatto (2007) also evaluated the program based on surveys. He conducted a research study to examine the reliability of student evaluations of summer undergraduate research experiences using an initial survey and a follow-up survey which was administered 9 months later.

First of all, Lopatto (2004) suggested that there is a high consistency between the survey of undergraduate research experiences (SURE) and the follow-up survey. The students who discontinued postgraduate education also reported significantly lower gains. The results indicated that students rated gains in "readiness for more demanding research" and "understanding how scientists work on real problems" highly, while "learning ethical conduct," "skill in science writing," and "skill in oral presentation" were the lowest rated gains. The results also showed that many students began or continued to plan for postgraduate education in the sciences.

Ellington, Wachira, & Nkwanta (2010) also indicated the results of the gains in the REU programs. They designed the REU program to increase upper-level undergraduate students' (N=5) understandings of the principles and challenges of interdisciplinary research in molecular biology and discrete mathematics. The results of the six-week program indicated that the students gained knowledge and skills (skills of applying mathematics to modeling problems of biology, skills for solving and manipulating generating functions, scientific presentation skills and research skills) in bioinformatics, and an awareness of the applications of discrete mathematics to research problems in biology. The authors used weekly and final reports and found that students improved their conceptual understanding of integrated mathematics and biology concepts. Students also demonstrated positive attitudes toward interdisciplinary content and research. In addition, most of the students designed their own research that was related to the project and presented their study at different conferences (Ellington, Wachira, & Nkwanta, 2010).

In general, the results of the studies indicated that students' scientific reports writing skills were the lowest rated gains in the REU programs. Kardash (2000); Seymour, Hunter, Laursen and Deantoni (2004); Hunter, Laursen and Seymour (2006); and Lopatto (2007) reported that few students have the ability to write scientific reports after having the research experience. Qu (2004) also reported similar results about an REU program which included ten participants. Students participated in semiconductor manufacturing research projects under the supervision of their faculty advisors. Students also attended general research seminars, weekly project meetings, and biweekly REU group meetings, seminars on research topics, remote interaction, and project defense sessions. The research outcomes suggested that it was challenging for faculty advisors to keep the REU students motivated and involved in the research seminars and during their project selection. REU students were more able to choose a research topic that is related to the research project that provided them opportunities to communicate with graduate students and scientists. Students completed their research in the summer (12 weeks), but they could not write the reports, so additional time was given to them. However, after the completion of their REU projects, still more work was required for publications (Qu, 2004).

The studies' results indicated that to gain the ability to write scientific research reports in the REU programs (especially for the publications) is very difficult because of the time constraints. REU programs generally take six to ten weeks. The studies indicate that this time is not sufficient for gaining a higher-order thinking skill like producing full research reports. The importance of time for gaining this writing skill is stressed by Qu (2004), as well as Zydney, Bennett, Shadid, & Bauer (2002). They reported the perceptions of science and engineering faculty members about undergraduate research programs. Their results suggested that the faculty who supervised undergraduates for two or more years believed the impact on cognitive and personal skills, the skills of developing intellectual curiosity, thinking logically about complex materials, synthesizing and using information from diverse sources, approaching problems creatively, maintaining openness to new ideas, and understanding ethical implications were significantly greater than those respondents who typically supervised undergraduate researchers for one year or less (Zydney, Bennett, Shadid, & Bauer, 2002).

Laursen, Hunter and Seymour (2010) reported that based on the results of their study there were six major types of benefits of research experiences for the students: personal/professional gains; intellectual gains; gains in professional socialization; gains in skills; enhanced preparation for graduate school and work; and career clarification and conformation. Laursen, Hunter and Seymour (2010) and Seymour, Hunter, Laursen and Deantoni (2004) suggested that REU programs help students to decide to go to graduate school and to clarify career plans. Like them, Delatte (2004) also reported the effects of REU programs on students' decisions about pursuing masters and PhD degrees. In this REU program, students (N=33) worked with the professors on several activities such as literature reviews, computer modeling, laboratory testing, and field research. In order to evaluate the program, students were surveyed at the beginning, at the end, and six months after the program. The results indicated that the program helped the students to decide whether they want to continue to graduate school. These results suggest that programs may help the students to identify their interests in graduate degrees. Students' interest in receiving a doctorate degree decreased slightly. This may be because they may not have realized the level of effort that they need to use for independent research. Also, students' research skills, recognition of their importance, confidence, and understanding of the importance of ethics significantly increased (Delatte, 2004).

Yarnall and Neff (2007) reported similar results in terms of the effects of REU on students' career plans. Each year 12–16 students attended the program. In the evaluation of the program, students reported that their involvement encouraged future research in Human-Environment Studies, to pursue graduate work or employment in the field of geography, and to do collaborative research. Overall, students rated their research process activities such as interviewing, coding processes, video conferences, codex, concept mapping, and the writing of final papers as highly positive.

Overall, URE programs (including REUs and other research experiences of undergraduates) help students to clarify their career plans, to decide whether or not they want to go to graduate school and complete a masters or PhD degree, and to refine their decisions about how to work in their fields. In addition, the participants indicated personal and professional gains; intellectual gains; gains in professional socialization; gains in research skills such as orally communicating, observing and collecting data, relating the results to the "bigger" picture in the field, and understanding contemporary concepts in the field; gains in understanding how science research is done and in applying their critical thinking and problem-solving skills to research; and gains in their ability to develop a research question and design.

Research Experiences for Teachers (RET) Programs

Description and purposes of the RET programs. Teachers need to have skills which are required to do scientific research (Musante, 2006). The National Science Teachers Association requires that "teachers of science must demonstrate that they understand the process, tenets, and assumptions of multiple methods of inquiry leading to scientific knowledge, and how to engage students successfully in developmentally appropriate inquiries that require them to develop concepts and relationships from observations, data, and inferences in a scientific manner" (NSTA, 2003, p.18). The National Science Foundation (NSF) has supported Research Experiences for Teachers (RET) programs for more than 20 years in order to achieve this goal. The NSF funds RET programs via the Directorates for Engineering (ENG) and Computer & Information Science & Engineering (CISE). It supports the participation of K-12 teachers who are in STEM fields and community college faculty in engineering and computer science. The main goal of RET programs is to engage teachers in engineering and scientific research, work collaboratively with the faculty and research community, and help them to translate their research experience into classroom teaching (NSF, 2012).

RET programs provide teachers opportunities for meaningful research experiences that improve their understandings of scientific research (NRC, 1996; Ononye, Husting, Jackson, Srinivasan, Sorial, Kukreti, 2007), and the teachers have the opportunity to reach a sophisticated understanding of how scientists do research. Teachers work as scientists with professors and graduate students and are embedded in the environment of scientific research (Grove, Dixon, Pop, 2009, Ononye et al., 2007). In the RET programs teachers typically are placed in research laboratories that allow them to be involved in real-world scientific research, typically over six or eight weeks. Some programs are small (generally with one or two teachers in a university laboratory), while some are large, placing more than 10 teachers in industry and university laboratories. These programs provide support for translating their experience into classrooms and workshops to provide new knowledge (Pop, Dixon & Grove, 2010). The evaluation of these programs showed that they provide teachers with real-world research strategies (SRI International, 2007).

Outcomes of the RET programs and teachers' research experiences. The outcomes of the RET programs are presented below.

The impact of the RET Programs on teachers' understandings of the nature of science (NOS), scientific research and scientific research skills. In this section, the literature about RET programs is presented (Table 2). Before explaining the impact of the RET programs on teachers' understandings of the nature of science and scientific research, it is important to clarify the differences between NOS and scientific inquiry.

Although the meaning of the nature of science has been changed by philosophers of science, historians of science, and science educators, there is a general agreement that it refers to the epistemology of science and science as a way of knowing. It also means the values inherent to the development of an individuals' scientific knowledge. NOS refers to characteristics of science and scientific knowledge, and its characteristics clearly distinguish it from other disciplines. These characteristics are: science is tentative, empirical, subjective, and socially and culturally constructed; and also involves imagination, creativity, observations, and inferences (Lederman, 1992; Lederman, 1999).

Table 2.
The citations, methods and results of the RET programs

Citation	Methods	Results
Dixon, P., & Wilke, R. A. (2007). The influence of a teacher research experience on elementary teachers' thinking and instruction. *Journal of Elementary Science Education, 19*(1), 25-43.	• Six week summer RET program • Sixty-seven elementary and middle school teachers • Survey and interview were used	• Elementary teachers indicated more changes to their teaching practices; they increased confidence in teaching science. • Most middle school teachers reported no changes in their teaching style. • Changes occurred in teachers' thinking about teaching science, but not necessarily in an immediate classroom implementation of the RET practices.
Blanchard, M., R., Southerland, S. A., & Granger, E. M. (2009). No silver bullet for inquiry: Making sense of teacher change following an inquiry based research experience for teachers. *Science Education, 93*, 322-360.	• A 6-week, marine ecology RET program • Four secondary science teachers • Questionnaires, interviews, classroom recordings, STIR instrument were used	• Teachers who entered the program with more sophisticated, theory-based understanding of teaching and learning were more apt to understand inquiry as a model and to use classroom-based inquiry throughout their teaching following the program. • Despite an explicit program focus on reflection, a clear model of scientific inquiry, direct engagement of the teachers, and follow-up that engaged teachers in further reflection on their practices, there still was impediments to teacher change.
Roseler, K., Nguyen, G., Golden, B., & Southerland, S. A. (2012). A summary of impacts of two distinct RET (Research Experience for Teachers) programs: An analysis of 5 years of data. Paper presented at the annual meeting of the American Educational Research Association, Vancouver B.C., April 13-17, 2012.	• SciPed and SciRes RET programs • More than 100 RET participants from elementary, middle and high school	• RETs improved teachers' beliefs about pedagogical discontentment and reform and they can support changes in teacher practices. • Although SciPed program that focused more pointedly on teacher practice was more successful in shaping teachers' beliefs and practices teachers still need to have explicit help in translating scientific inquiry into their teaching knowledge and practice.
Brown, S., & Malear, C. (2007). Preservice teachers' research experiences in scientists' laboratories. *Journal of Science Teacher Education, 18*, 573-597.	• 15 weeks botanical or zoological research • Three preservice secondary science teachers worked with a research scientist • Interview transcripts, laboratory notebooks, and reflective summaries	• Although teachers acquired scientific skills and content knowledge; they expressed limited use of these in their classrooms.
Raphael, R., Tobias, S., & Greenberg, R. (1999). Research experience as a component of science and mathematics teacher preparation. *Journal of Science Teacher Education, 10*(2), 147-158.	• Six weeks RET program in biology, biomedicine, astronomy, geoscience, physics, and science education • 75 preservice teachers from math and science • Students' research reports and an exit interview were conducted	• RET programs increased preservice teachers' understanding of the scientific method, how science is conducted and the ability to communicate what scientist actually do. • Some preservice teachers learned and implemented new pedagogical strategies due to participating in the program.

Table 2 *(Continued)*

Feldman, A., Ozalp, D., & Alshehri, F. (2012). The Impact of an REU and RET Program on Participants' Scientific Research Skills.	• Eight weeks in environmental engineering RET program • One preservice and 8 science and math teachers • Surveys, interviews, observations were conducted	• When the teachers were asked midway through the program to reflect back on their understanding about the research skills at the beginning the teachers tended to decrease their ratings. • This result was expected because people tend to overrate their skills at the beginning of an educational program. As they learn, they realize that they knew less than they thought when they began the program.
Westerlund, J. F., Garcia, D. M., Koke, J. R., Taylor, T. A., & Mason, D., S. (2002). Summer scientific research for teachers: The experience and its effect. *Journal of Science Teacher Education, 13*(1), 63-83.	• Eight-week summer RET in biology, physics n • Twenty three secondary school teachers. • daily journal, open thoughts inventory, interviews, focus group meeting, pre- and post-tests	• Increased content knowledge, enthusiasm for science, and expanded opportunities for participation in scientific dialogues. • There is a change in the way students view teachers, with teachers being viewed as participants in scientific research and increased enthusiasm about science due to increased laboratory and field activities. • Increased teachers' inquiry based practices.
Schwartz, R. S., Westerlund, J. F., Garcia, D. M., & Taylor, T. A. (2010). The impact of full immersion scientific research experiences on teachers' views of the nature of science. *Electronic Journal of Science Education*, *14*(1), 1-41.	• 8-week summer research program • Forty secondary science teachers • Pre/post internship, views of the nature of science questionnaires, interviews, and videotapes of group sessions	• Teachers in the non-explicit group made minimal in understanding NOS. • Although the explicit group teachers made substantial gains in understanding the nature of science their perceptions of the nature of science were still ambiguous.
Herrington, D. G., Luxford, K., & Yezierski, E. J. (2012). Target inquiry: Helping teachers use a research experience to transform their teaching practices. *Journal of Chemical Education, 89*(4), 442−448.	• Ten RET websites • Six−eight weeks RET programs • Teachers' chemistry lesson plans were used and analyze with SLPAIR instrument.	• Many of the chemistry lessons developed and posted by chemistry teachers as part of traditional RET programs do not meet these standards.
Grove, C. M., Dixon, P. J., & Pop, M. M. (2009). Research experiences for teachers: Influences related to expectancy and value of changes to practice in the America classroom. *Professional Development in Education, 35*(2), 247-260.	• Six weeks RET program • Thirteen K–12 teachers • Teachers worked with a mentor scientist in a science laboratory	• Teachers indicated increase in positive and accurate statements concerning implementing inquiry-based science practices. • Although the participants discussed changes to their beliefs some changes to practice were seen in observations to be more subtle in the classroom than as reported in interviews. • Teachers still faced barriers when they implement inquiry-based practices.
Ononye, G., Husting, C., Jackson, E., Srinivasan, R., Sorial, G., & Kukreti, A. (2007). Research experience for teachers (RET): The art of formal education. *Journal of environmental engineering, January*, 2-3.	• RET program in an environmental research lab • Four math and science teacher groups	• The research lab helps to clarify the concepts in the field like nanotechnology, environmental chemistry, scientific method, and lab safety. • In the RETs teachers have the opportunity to work closely with engineers and students to develop effective problem-solving strategies
Klein, S. S. (2009). Effective STEM professional development: A biomedical engineering RET site project. *International Journal of Engineering Education, 25*(3), 523-533.	• Twenty-four day biomedical engineering RET program • Forty-four high school teachers • Surveys were used	• RET program made a positive effect on engaging teachers in meaningful research experiences that allowed them to experience and understand the research process and giving them the ability to relate this to their students.

Those key characteristics have been referred to as a "consensus list" of the nature of science (Allchin, 2011). While many science educators agree with those key components, some researchers disagree and criticize them. For instance, Matthews (2012) offered replacing the phrase 'nature' of science (NOS) with 'features' of science (FOS) in order to cover a more inclusive range of ideas about science, rather than strictly following the aspects in the consensus list. On the other hand, Allchin (2011) suggested "reframing current NOS characterizations from selective lists of tenets to the multiple dimensions shaping reliability in scientific practice, from the experimental to the social, namely to Whole Science" (p. 518). Allchin (2011) argues that the "consensus view" NOS list lacks ideas about science such as the role of funding, motivations, peer review, biases, and the validation of the instruments.

The NOS and scientific research are different concepts and, in general, there is confusion between the meanings of them. Although it is still debated, science can be defined as having at least three aspects: body of knowledge, process/method, and a way of constructing reality (Lederman, 1992). As the differences between these three aspects are not totally clear, there is confusion among the nature of science and science process. Science processes produce knowledge of science. Therefore, scientific knowledge is a direct result of both the processes and epistemological commitments of science. These three aspects of science are related to each other, but at the same time they have different characteristics. Nature of science is the term that is used to distinguish science from other disciplines (Lederman & Niess, 1997). Understanding how to do scientific research does not mean understanding the characteristics of the nature of science. Lederman & Niess (1997) explain it with these words: "Teachers have been led to believe that their students will come to understand the nature of science simply through the performance of scientific inquiry and/or investigations. This advice is no more valid than assuming that students will learn the details of cellular respiration by breathing or watching an animal breathe" (Lederman & Niess, 1997, p.2). In short, while the nature of science is the characteristics of science that distinguish it from other disciplines, scientific research is the process that involves activities such as asking questions; making literature review; making observations; collecting, analyzing, and interpreting data; constructing explanations and communicating the results (Lederman & Niess, 1997).

Lederman (2007) emphasized that NOS and science processes or scientific inquiry overlap and interact in important ways; however, there are differences between those two as well. While scientific inquiry involves different science processes that include activities such as observing and inferring, NOS is related to the "epistemological underpinnings of the activities of science" and the characteristics of the knowledge. He states that scientific inquiry and NOS are different, but at the same time they are related. In addition, they are both important to teach in the classrooms. As stated by Lederman (2007), there are many studies which indicate that inquiry fosters learning about NOS. For instance, Deng et al. (2011) reviewed the empirical studies about the curriculum interventions intended to change students' views on NOS that were published between 1992 and 2010. They reported several studies which included inquiry activities combined with other learning activities that improved NOS learning. In addition, Lehrer, Schauble, and Lucas (2008), and Yacoubian and BouJaoude (2010) also conducted studies that indicated improvement on NOS learning through inquiry.

Allchin, Andersen and Nielsen (2014)'s research also advocated that student-based investigations or classroom inquiry that is well managed is helpful in developing basic skills in the process of science and a corresponding understanding of their epistemic purposes. They also emphasized that student based- inquiry is a powerful tool for NOS learning, but it also needs to be supported by using others methods. Duschl and Grandy (2013) analyzed two different ‘explicitly teaching’ NOS approaches (Version 1 and Version 2) in pre-college programs. In Version 1, teachers explicitly connect the consensus statements to features of science lessons and activities, which suggests that inquiry and NOS are separate. Version 2 supports the importance of embedding students’ enactments of the scientific practices in domain-specific contexts over longer teaching sequences and it advocates inquiry and NOS as coupled. They found that Version 2 is more effective than Version 1 in NOS learning because “it develops the critical epistemic cognitive and social practices that scientists and science learners use when (1) developing and evaluating scientific evidence, explanations and knowledge and (2) critiquing and communicating scientific ideas and information; thereby promoting science literacy” (Duschl & Grandy, 2013, p. 2109).

The above overviews detail what NOS is, the criticism regarding the consensus of views about NOS, and how it is related to scientific inquiry. I now turn to the debate in this section regarding how participation in the research experiences affects teachers’ NOS views and then I focus on the science practices later in my dissertation.

In order to find out the impact of a research experience on teachers’ NOS views, Schwartz, Westerlund, Garcia, and Taylor (2010) conducted an 8-week summer research program to compare secondary science teachers’ conceptions of the NOS in full immersion of scientific research programs with and without explicit NOS instruction. All teachers were paired with research scientists and participated fully in scientific research. The explicit NOS instruction group (N=21) did activities which explicitly addressed NOS each week. The non-explicit group did not receive this instruction. The results indicated that teachers in the non-explicit group made minimal gains in understanding NOS. Interestingly, although the explicit group teachers made substantial gains in understanding the nature of science, their perceptions of the nature of science were still ambiguous.

The results suggested that the explicit NOS instruction made positive effects on teachers' understanding of the NOS but provided limited reflection opportunities for teachers to challenge their NOS understanding. These results reflect Lederman & Niess's (1997) explanation about the distinction between NOS and scientific process. In this case, although teachers did the scientific research their NOS perceptions remained ambiguous.

Raphael, Tobias, & Greenberg's (1999) study included 75 preservice teachers in a research program in the biology, biomedicine, astronomy, geoscience, physics, and science education departments over the course of six weeks. Participants worked in research projects with the faculty mentors, and at the end of the program they wrote research reports which included results of their projects. In order to find out the outcomes of the program, students' research reports were reviewed and an exit interview was conducted. In the interviews, students reported that the program improved their understandings of the scientific method, how science is conducted, and the ability to communicate what scientists actually do.

Feldman, Ozalp, and Alshehri (2012) reported the outcomes of the evaluation of an environmental engineering RET program. They conducted Kardash's (2000) research skills survey at the beginning, in the middle, and at the end of the program. Interestingly, when they asked the teachers (N=9) midway through the program to reflect back on their understanding of the research skills at the beginning, the teachers tended to decrease their ratings. This result was expected because people tend to overrate their skills at the beginning of an educational program. As they learn, they realize that they knew less than they thought when they began the program.

Similar results were found for undergraduate students in an REU program (Feldman, Ozalp, & Johnston, 2011; Feldman & Ozalp, 2012).

Brown and Malear (2007) designed an apprenticeship course to provide preservice secondary science teachers opportunities to engage in an authentic inquiry. Three pre service teachers worked with a research scientist in novice roles where they actively engaged in constructing knowledge. Data were derived from interviews, laboratory notebooks, and reflective summaries of the students. Although teachers reported their research skills and content knowledge improved, they expressed the use of those gains in classrooms were limited. Some preservice teachers claimed their confidence in incorporating inquiry methodology improved, but the researchers did not measure if this actually occurred (Brown & Malear, 2007).

First of all, even though teachers reported their confidence in inquiry methodology increased, we cannot know if this really happened because this result is only based on teachers' self-reports; the study did not demonstrate whether they can show it in their teaching. From teachers' explanations we can conclude that they do not totally conduct research in their teaching because, interestingly, they think of teaching science and doing scientific research as mutually exclusive in secondary school classrooms.

Klein (2009) conducted a twenty-four day biomedical engineering RET project to give the teachers a broad overview of biomedical engineering. Forty-four high school teachers completed a research project in a biomedical engineering laboratory, designed lesson plans based on that research experience, and implemented the plans in their classrooms. The researchers conducted surveys to measure teachers' attitudes and self-reflection (SRI, 2007). The results suggested that the RET program had a positive effect on engaging teachers in meaningful research experiences and understanding the research process, as well as giving them the ability to relate this to their students. The result also indicated that the teachers' self-confidence increased about their views of the importance of science research in the classroom.

As in Brown and Malear's (2007) study, these results also have the same issue regarding self-reporting. In this article, the authors also stressed this problem. They expressed that this study data is self-reported, which implies that it may be exaggerated or enhanced, or perhaps the reverse. This means that participants may answer the questions to please the research team with positive results. This is a possible explanation because the researchers did not investigate the extent to which the teachers' local school contexts or backgrounds may have influenced their responses.

The impact of the RET programs on teachers' classroom teaching practices and content knowledge. Pop, Dixon & Grove (2010) conducted a 6-week summer RET program that included sixty-seven elementary and middle school teachers. The study also indicated elementary teachers were better able to understand how to implement changes in classroom teaching and were more eager to learn. They also indicated that the program improved their teaching practices which were related to pedagogical aspects like delivering different types of science activities, teaching science in different ways, and increased confidence in teaching science. In their interviews, most middle school teachers stated that no changes occurred in their teaching style, while some teachers specifically stated pedagogical changes. The findings of this study suggested that overall, for both elementary and middle school teachers, changes occurred in teachers' thinking about teaching science, but not necessarily in an immediate classroom implementation of the RET practices.

Another study included one elementary, two middle school, and six high school teachers, Working with a scientist for six weeks, they participated in workshops on writing in science, content lectures, online journaling, peer mentoring, share fairs, showcases of lesson plans, manipulatives for the classroom, unit plans, and equipment designed for the grade level they teach. Data from classroom observations, pre- and post-interviews, document analysis of journals, and case studies indicated that after participating in the program, they started to feel more confident in allowing their teaching to be guided by questions. They shifted from a top-down management style to a more student-centered approach, but they were still struggling with translating their experience fully into their classrooms (Dixon & Wilke, 2007). These results are similar to Pop, Dixon & Grove's (2010) study. The researchers explained that although it is assumed the research experiences have an influence on teachers' thinking and practice, there has been little evidence to support such assumptions. Their investigation suggests both positive outcomes, as well as areas for improved teacher learning (Dixon & Wilke, 2007). Grove, Dixon, and Pop (2009) found similar results in their research. In their RET program, thirteen American K–12 teachers spent six weeks with a mentor scientist in a nationally recognized science laboratory. Although the participants discussed changes in their beliefs about science teaching, observations indicated fewer changes in their classroom teaching than as reported in interviews. The results also suggest teachers still faced barriers in their teaching practices.

Preservice Teachers' Research Experiences

Outcomes of preservice science teachers' research experiences. In the literature, there are some studies about preservice teachers' research experiences in summer programs or in courses which include completing scientific research. The studies and their findings are explained in this section (Table 3).

Dresner and Worley (2006) reported a study which examined some long-term impacts of a professional development program, Teachers in the Woods (TIW). This five-week summer institute program provided ecology research experiences for preservice science teachers in several places such as national forests and national parks. Teachers also had an opportunity to participate in workshops to ensure transfer of new skills to the classroom. During the program teachers worked with scientists on a variety of research projects. In addition, they received training in forest ecology and field techniques to improve their knowledge about the use of sets of ecological field research protocols. The results of the study indicated that engaging in real-world field science research increased teachers' ecological knowledge and skills. The other reported result of the research was that the collegiality among teachers and scientists developed during the period of field improved their science learning. The experience also provided opportunities for the teachers to discuss pedagogy-related issues. Five years later, the participants indicated that they continued to apply what they had learned in the program. These teachers reported that they started field ecology projects at their school site and changed their classroom environments.

Another study conducted by Barnes, Hodge, Parker and Koroly (2006) examined how participating in the Teacher Research Update Experience (TRUE) program affects science and mathematics teachers' knowledge and skills of science. The results of the study indicated that this program satisfied participants' expectations from a teacher professional development program. The results also indicated that the participants who had particularly good science backgrounds and who were satisfied with their lab placements reported their scientific knowledge and skills were improved. On the other hand, those who were dissatisfied with the lab experience were the teachers whose professors were absent much of the time. These participants suggested that they needed more guidance to complete their projects.

Table 3.
The citations, methods and results of the research experiences of the preservice teachers

Citation	Methods	Results
Dresner, M., & Worley, E. (2006). Teacher research experiences, partnerships with scientists, and teacher networks sustaining factors from professional development. *Journal of Science Teacher Education*, *17*, 1–14**.**	• 5-week Teachers in the Woods (TIW) summer program provided ecology research experiences for preservice science teachers at a variety of national forests and national parks. • During the program teachers worked with scientists on a variety of research projects for four weeks.	• Engaging in real-world field science research increased teachers' ecological knowledge and skills. • The collegiality among teachers and scientists developed during the period of field work can enhance science learning. • They continued to apply what they had learned in the program. • They started field ecology projects at their school sites, changed their classroom environments, and implemented long-term student science projects
Barnes M. B., Hodge E. M., Parker, M., & Koroly, M. J. (2006). The teacher research update experience: Perceptions of practicing science, mathematics, and technology teachers. *Journal of Science Teacher Education*, *17*, 243–263.	• Teacher Research Update Experience (TRUE) perceived their experiences in summer 2000	• This program satisfied participants expectations from a teachers professional development program • The participants particularly who had good science backgrounds who enjoyed their lab placements and their expectations were met about increasing their scientific knowledge and skills. • Those who were dissatisfied with the lab experience had professors who were absent much of the time. • Participants found the skills they developed and the knowledge they acquired from the computer sessions were beneficial.
Malear, C. T., Goodlaxon, J. D., Ware T. R., & Hickok, L. G. (2000). Teaching preservice science teachers how to do science: Responses to the research experience. *Journal of Science Teacher Education*, *11*(1), 77-90.	• Participation in a course to have research experience. • Students participated in research studies with scientists	• Students showed development of scientific thinking and also they successful designed and presented their self-initiated experiments both orally and in written form. • Students became self-motivated, skills in communication and critical analysis. • They learned how to work cooperatively and independently and how to formulate the results of their research.
Gilmer, P. J., Hahn, L., & Spaid, M. R. (2002). *Experiential learning for pre-service science and mathematics teachers: Applications to secondary classrooms*, Tallahassee, FL: SERVE.	• CO-LEARNERS PROGRAM • Pre-service teachers worked with an inservice science teacher and a scientist in a research laboratory for one or two summers. • They conducted scientific research which is related to environmental science	• Pre-service teachers learned science content knowledge about earth science and biology, or biology and environmental science. • Most of them emphasized the importance of a pre-service teacher seeing the connection of the science to the real world. • Some teachers were novice at the beginning of the program but they learned how to utilize it for the science and for presentation of what they learned. • They had a lot of knowledge about the technology and started to use them in the program effectively

Table 3 *(Continued)*

Windschitl, M. (2004). Folk Theories of ‘‘Inquiry:’’ How preservice teachers reproduce the discourse and practices of an atheoretical scientific method. *Journal of Research in Science Teaching, 41*, 481–512.	• A course to help students develop a foundational understanding of science • Eight weeks research	• Participants shared a tacit framework of what it means to ‘‘do science’’ which shaped their investigations and influenced reflections on their inquiries. • Some of the participants’ research models were congruent with authentic inquiry but most of their assumptions in the research were misrepresentations of fundamental aspects of science including formulating a hypothesis • Although all participants held degrees in science, the participants who eventually used inquiry in their own classrooms were those who had significant research experiences in careers or postsecondary study and greater science-content background.
Brown, S., & Malear, C. (2007). Preservice teachers’ research experiences in scientists laboratories. *Journal of Science Teacher Education, 18*, 573–597.	• 15 weeks apprenticeship course • They conducted botanical or zoological research the scientists. • The researchers collected data from interviews, laboratory notebook, and reflective summary data resources	• Teachers learned scientific skills and content knowledge. • The teachers valued this experience from various perspectives and thought it was an experience that should be offered in the future.
Raphael, J., Tobias, S., & Greenberg, R. (1999). Research experience as a component of science and mathematics teacher preparation. *Journal of Science Teacher Education, 10*(2), 147-158.	• Future Teachers’ Research program • To preservice math and science teachers to do full summer research • Students worked with faculty members in the laboratory. • Interviews, reports and survey are conducted	• The teachers said that doing academic research is every valuable for their education and their understanding of science. • Participants also stressed that the program improved the likelihood that they would be able to communicate to their secondary students what scientists actually do. • The participants felt advantaged because they had chosen to expand their study of science and mathematics by doing research in an area unfamiliar to them, learning how to use the scientific instrument was one of the benefit of the program, the participants reported that their understanding of science method in action.

The results also indicated that all participants found the skills they developed and the knowledge they acquired from the computer sessions were beneficial, and they were very pleased about them.

Malear, Goodlaxon, Ware, and Hickok's (2000) conducted a study regarding involvement in a one semester-long research experience for preservice secondary science teachers. Their purpose was to teach the preservice teachers how to do science. For this purpose, they designed a course which is taught by scientists. Students participated in research studies with scientists. In addition to engaging in experiments, the participants had open access to the laboratory/classroom, and they had weekly and biweekly lab meetings in which they reviewed articles and discussed all parts including the literature, design of the study, data collection, analysis, and interpretation. The result of the study indicated that students had positive reflections about the class, all students showed development of scientific thinking, and they also successfully designed and presented their self-initiated experiments both orally and in written form. At the end of the program, students became self-motivated and improved their skills in communication and critical analysis. They also realized that they are responsible for gaining their own information. They learned how to work both cooperatively and independently and how to formulate the results of their research.

Gilmer, Hahn, and Spaid (2002) designed the CO-LEARNERS program to examine what preservice teachers learn through the process of doing science first-hand. In this program, pre-service teachers worked with an inservice science teacher and a scientist in a research laboratory for one or two summers. They conducted scientific research related to environmental science topics in which they used chemistry, biology, microbiology, earth science, and computer science methodologies. The results of the study indicated that pre-service teachers learned science content knowledge about earth science, biology, and environmental science. At the end of the program, most of them emphasized the importance of a preservice teacher seeing the connection of the science to the real world. Some teachers were novices at the beginning of the program but they learned how to utilize their learning for science and for presentations of what they learned. Teachers also possessed a lot of knowledge about the technology and started to use it in the program. The teachers emphasized that learning technology is very important for classroom applications.

Windschitl (2004) designed a course to help students develop a foundational understanding of science and to realize how scientists do research. In this methods class, the preservice teachers engaged in discussions about inquiry. They also engaged in independent inquiry projects. For these projects, students observed their neighborhood environments for one week. Then students designed an investigation, collected and analyzed data, and defended the research results to the class in a formal presentation. The total time for completion of the project was eight weeks. The results of the study indicated that participants' shared framework shaped their way of investigations and affected the reflections about their research. The study results also indicated that although all participants held degrees in science, only the participants who had previous research experiences and greater science-content background used inquiry in their own classrooms.

Another apprenticeship course was designed by Brown and Malear (2007) to afford preservice secondary science teachers opportunities to engage in an authentic research with a scientist in expert/novice roles for 15 weeks. The teachers worked at least nine hours each week. They conducted botanical or zoological research with scientists. Additionally, they met with the science teacher educator to discuss their research, and for additional guidance and support. The researchers collected data from interviews, laboratory notebooks, and reflective summaries. The results of the study indicated that teachers learned scientific skills and content knowledge. The teachers thought this experience is valuable and should be offered in the future.

Raphael, Tobias and Greenberg (1999) conducted research to report on the Future Teachers' Research program in order to provide an opportunity for preservice math and science teachers to do full summer research under direct supervision of faculty from the departments including biology, biomedicine, astronomy, physics, and science education. In this program, students worked with a faculty member in the laboratory on different research projects. Interviews, reports, and survey results indicated that the participants stated they had the opportunity to expand their study of science and mathematics by doing research in a different area. They also explained that one of the benefits of the program was learning how to use scientific instruments. The participants also stressed that the program improved their ability to communicate to their secondary students what scientists actually do. The teachers also pointed out that doing academic research is very valuable for their education and their understanding of science. Overall, the results for the preservice teachers' research experiences in apprenticeship, summer programs, or in the courses that were designed to teach scientific research had some positive impacts on teachers' scientific thinking.

The studies indicated that preservice teachers' research experiences programs improved their science research content knowledge and skills. One of the important points about the programs is that the motivation and satisfaction of the participants are affected by the professors' presence during the research process. If the professors are absent and they don't spend time with the teachers during the research, this situation affects teachers' satisfaction about the program.

The other important finding is that teachers' technological skills improved during the programs because, in general, teachers reported that they acquired knowledge and skills about technology.

Some of the studies indicated that preservice teachers' scientific thinking and oral and written communication skills increased after they participated in research. One of the benefits of these experiences is that these programs help teachers how to work cooperatively and independently in research groups. In general, after they participated in the research experiences, teachers reported that understanding scientific research is important for their development. Also, some of the participants' research models were congruent with authentic inquiry, but most of their assumptions in the research were misrepresentations of fundamental aspects of science, such as formulating a hypothesis.

Summary and Critique of the Literature

The studies about REU programs indicated that research experiences help undergraduates to gain a variety of important scientific research skills such as orally communicating, observing and collecting data, relating the results to the "bigger" picture in the field, understanding contemporary concepts in the field, critical thinking and problem-solving skills to the work at hand, including the capacity to analyze data in relation to scientific concepts, and theories framing research. On the other hand, the results also indicate that REU programs are limited in their ability to help students gain skills used by independent researchers, such as writing a research paper for publication, identifying a specific question for investigation, translating the question into a workable hypothesis, designing a theoretical test of the hypothesis, and reformulating the hypothesis based on one's experimental results. These skills are higher-order thinking skills, and they need more time to be improved. The results suggest that the length of the REU programs is very important for undergraduates to gain all the skills required for scientific inquiry. Most of the studies about the RET programs relied on self-reported surveys, but we don't know the real picture of the REU programs and how they affect undergraduates' research kills.

The studies in the literature indicated that RET programs improve teachers' content knowledge and research skills, and knowledge about technology. In general, teachers were satisfied with the experiences that they had in the RET programs. The studies also indicated that RET programs affect teachers' views about the importance of scientific research. The teachers stressed they started to think about the importance of doing research in their classrooms, and they also started to feel more comfortable when they do research with their students. The studies indicated that RET programs also affect teachers' practices in their classrooms. For example, some teachers start to do similar projects in their classrooms and they try to modify their classroom environment. But the studies also indicated that most of the teachers have difficulty implementing inquiry in their classrooms, and they felt they needed support in translating their experience. The teachers who wanted to create inquiry-based classrooms especially needed extra support to translate the experience.

The studies indicated that the research experiences improve teacher research skills, but the skills that require higher order thinking are the ones that were least improved. Based on this result, we can say that RET programs are limited in their ability to help teachers improve higher order research skills such as writing a report and reformulating the original hypothesis or research question. This finding is also reported in the REU studies. The reason might be the nature of the short term research experiences of the programs. Therefore, we can say that in order to improve these skills the length of the research experience is very important. The studies about the RET programs report how these programs affect teachers' research skills, but none of the studies show what teachers know about these science skills. Teachers are expected to teach science and do science in their classrooms to improve students' science practices. Therefore, it is important to know teachers' understandings of research skills and how research experiences affect their understandings. Improvement in their self-reported research skills does not mean that their understandings are also improved. Therefore, it is very important to know how research experiences affect teachers' understandings of science practices or research skills.

The studies about the preservice teachers' research experiences indicated that engaging in real-world field science research increased preservice teachers' content knowledge. The collegiality among teachers and scientists during the research is very important in teacher improvement. Research experiences programs generally satisfied the preservice teachers, and they started to apply their experiences in their classrooms. The teachers started to see the importance of scientific research in science teaching, and they felt advantaged because they had the research experience before they started to work in their classrooms. Preservice teachers improved their research skills but not their higher-order skills. Research experiences also improved teachers' self-confidence when they communicated about their research. The studies also indicated that professors' interest in the preservice teachers while they work in the research is very important because the teachers who believed the professor did not spend enough time while working in the projects felt more dissatisfaction.

In short, research experiences are beneficial for the undergraduates, teachers, and preservice teachers. These experiences improve the participants' research skills but not the ones that require higher-order thinking abilities. These experiences help teachers to change their classroom environments into more research-based ones. However, it is also obvious from the studies that even as teachers started to change their view about scientific research they still need support to translate their experiences into their classrooms. Also, most of the studies relied on self-reported survey data about participants' research skills, but we don't know what their understandings of these skills are. The NRC (2012) published the new Framework and explained the science practices that teachers and students need to know to do science. Teachers need to apply these practices in their classroom. In order to apply these practices they need to know what the science practices mean. Therefore, it is important to know what science teachers' understandings are about science practices. However, despite its importance, this part is missing in the literature. If we expect teachers to do science and use and teach science practices in their classrooms, we should know what their understandings are about them. However, none of the studies found out their understanding about these science practices and research skills. Also, the studies don't show how research experiences affect their understandings about these science practices. Therefore, this study found out teachers' understandings of science practices and how research experiences affected their understandings and abilities of engaging in science practices. Additionally, sources of different changes in their understandings and abilities were determined in this research.

CHAPTER THREE:

METHODS

Purpose of the Study

The purpose of this study was to find out science teachers' understandings of science practices before and after they participate in an environmental engineering RET program. Also, the other purpose of this study was to identify how teachers' participation in the RET program affects their ability to engage in science practices. The study also found out the sources that cause the differences in the RET teachers' change in their understandings of science practices and abilities to engage in science practices.

Research Questions

The study examined environmental engineering RET teachers' understandings of science practices before and after they participate in the RET program. The teachers participated in an environmental engineering RET program, and they worked in different research projects with professors and graduate students from environmental engineering and public health programs. Therefore, it was also interesting to find out teachers' change in each of these science practices. In addition, finding out the sources of the differences in the teachers' change in their understandings and abilities to engage in science practices completed the big picture of the study. The research questions of this study were:

1. How does the participation in the RET program affect science teachers' abilities to engage in science practices?

2. How does science teachers' participation in an environmental engineering RET program affect their understandings of science practices?

3. What are the sources of differences in the RET teachers' change in their understandings of science practices and ability to engage in science practices?

Research Design

Mixed Methods

In recent years, many researchers agree with the idea that qualitative and quantitative research can complement each other. This means that the combination of quantitative and qualitative methods can provide better insights into the research for the same problem situation. Also, this may allow asking more interesting questions for future research than if only either qualitative or quantitative studies are considered (Gall, Gall, & Burg, 2007).

Mixed methods research is considered a research design that has the methods of inquiry. Its methodology involves philosophical assumptions that shape the mixture of qualitative and quantitative data collection and analysis. It combines quantitative and qualitative methods in the design of a single study (Cresswell, 2006; Gall, Gall, & Burg, 2007; Johnson & Onwuegbuzie, 2004) by focusing on collecting, analyzing, and mixing both kinds of data. The major purpose of combining two methods is to provide a better understanding of research problems than either approach alone (Cresswell, 2006). Therefore, "mixed methods research is the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study" (Johnson & Onwuegbuzie, 2004, p.17).

Mixed methods research is an expansive and creative form of research. It does not restrict or constrain researchers because it uses multiple approaches in order to find answers to the research questions. Some research questions and combinations of questions can be better answered through mixed methods research. In order to apply mixed methods research, researchers should consider all of the relevant characteristics of quantitative and qualitative study (Johnson & Onwuegbuzie, 2004).

Qualitative research locates the researcher as an observer of the world through different practices that make the world visible. These practices transform the world into interviews, field notes, recordings, and other representations that show the situations of the natural settings. Therefore, qualitative researchers make observations in their natural settings to make sense of the phenomena and to find the meanings people bring to them (Denzin & Lincoln, 2008).

Cresswell (2006) listed the characteristics of mixed methods research as below:

- Some research problems can be evidenced by conducting mixed methods research rather than either quantitative or qualitative research alone because in this method researchers can use all of the tools of both qualitative and quantitative data collection available, rather than being restricted to the qualitative research or quantitative research methods alone.
- Some research questions cannot be answered by only using qualitative or quantitative methods. In these situations using only one approach would not provide a satisfactory answer. Therefore, mixed methods research helps to answer these types of research questions.
- In the situations that have an adversarial relationship between quantitative and qualitative researchers, mixed methods research encourages researchers to collaborate across this problem.

- In addition to combining qualitative and quantitative approaches in a single study, mixed methods research uses multiple worldviews or paradigms rather than the certain paradigms for both kinds of research. Therefore, it allows us to think of multiple paradigms for a single research design.
- In a mixed methods research design, the researcher can use all methods possible to address a research problem. Therefore, they can solve problems using both numbers and words; they combine inductive and deductive thinking, observe people, and record their behavior. Because of these characteristics, mixed methods research is practical. Therefore, it is natural for researchers to use mixed methods research as the preferred way of understanding the world.

The research design of this study was mixed methods that combined quantitative and qualitative research approaches into a single study. In order to find out teachers' understandings of science practices, qualitative data collection methods were used. Pre and post semi-structured interviews with the teachers were conducted to find out what each science practice means to the teachers before and after they participate in the RET program. In order to find the teachers' abilities to engage in science practices, both qualitative and quantitative data collection methods and analysis were used. To find that out, Likert scale abilities of science practices surveys were conducted with the teachers (pre, mid, post), professors, and the graduate students (beginning, end). The surveys were the quantitative methods used in the study. In addition, teachers, professors, and graduate students were interviewed; and observations and document analysis such as poster presentations were examined. Therefore, this study combined the qualitative and quantitative data collection approaches. And finally, to find out the sources of differences in the RET teachers' change in their understandings of science practices and abilities to engage in science practices, qualitative collection and analysis methods were used. At the end of the data collection and analysis all the qualitative and quantitative findings were combined to provide the overall picture of the results of the study. With these considerations, this study contains characteristics of mixed methods research design.

Case Study

Gall, Gall, and Borg (2007) define case study research as "(a) the in depth study of (b) one or more instances of a phenomenon (c) in its real life context that (d) reflects the perspective of the participants involved in the phenomenon (p. 447)." The phenomenon in a case study represents a process, event, or person. Therefore, a phenomenon can be a program, curricula, roles, and events, and a case is particular instance of a phenomenon (Gall, Gall and Borg, 2007). "The desire to evaluate individualized client outcomes is one major reason why case studies may be conducted. The need for case study data may be present whether the unit of analysis is an individual, program, organization, or community" (Patton, 1990, p. 99).

In this study, two teachers were selected for the case study. First, I present those two teachers' background information and what they experienced in the RET program. The purpose is to make better connections between the teachers' backgrounds, what they experienced and learned in the RET program in terms of engaging in science practices, and how those features affected their understandings of science practices. I provided in-depth analysis of each case by examining them separately. Those two teachers were selected as cases based on their experiences and also whether their abilities and understandings of science practices improved in the RET program. The analysis indicates that they should be presented as cases to represent the teachers in terms of their experiences and improvements in the program. The first case, Ivette, showed an increase in both her understandings and abilities of science practices. The second case, Ashlynn, did not show much increase in either criterion. Therefore, they were selected as cases for the study. The names of Ivette and Ashlynn are pseudonyms.

Site Selection

The context of the study was a Research Experiences for Teachers (RET) program supported by the NSF. It was located in a U.S. university Environmental Engineering Program. The Environmental Engineering Program professors' research interests are generally management of the nitrogen cycle, access to clean water, and urban water infrastructure improvement. Therefore, teachers worked on the projects that focus on one of these topics.

The following are the objectives for the RET program as stated in the funding proposal to the National Science Foundation:

> 1) Train existing and upcoming teacher participants in the steps required for authentic scientific research;
>
> 2) Partner RET participants with USF faculty and their classes to create and implement innovative middle and high school curriculum that broadens participation in STEM fields through the use of relevant place based community engaged research projects, technology integration, language learning attention, and tiered mentorship opportunities linking K-12 and communities with university faculty and students;
>
> 3) Establish a sustainable mechanism for broadening participation in academic STEM research that meets targets of at least 50% women and 50% underrepresented minority RET participants who work in schools that have above average in the state percentages of students qualified for free or reduced lunches (> 51%) and/or English language learners (>12%); and

4) Create a collaborative group of university, K-12 and community participants that advances faculty research, meets local agency needs, and improves communities (NSF Proposal, 2012, p.15).

Intervention Design

In this section I explain the timeline of each data collection instrument that were administered before, at the beginning, in the middle, at the end, and after the program (Table 4).

Before the RET Program

The initial data from the pre-surveys and interviews were collected before the program. Approximately one week before the program teachers completed the Teachers' Abilities Engaging in Science Practices Pre-Survey (Appendix C). This self-assessment survey measures teachers' ability to engage in science practices. In addition to this survey, the teachers were interviewed in order to find out their understandings of science practices before the program (Appendix A: Teachers' Understandings of Science Practices Pre-Interview).

First Week of the RET Program

On the first day of the program teachers completed the Teachers' Abilities Engaging in Science Practices Pre-Survey (Appendix C) one more time. In order to find out test/retest reliability, the same test/survey should be completed by the same participants. For this reason, the RET teachers filled out the survey two times--before and on first day of the program, respectively. In terms of the activities, teachers attended the orientation session, which included safety training, research laboratories tour, library searches/teach engineering digital library, and curriculum templates with a review of rubrics and author submission information workshop. During this week, teachers and the professors also discussed and began their research. I observed the activities of the teachers, such as the workshops that they attended and their lab work

(Appendix H). In order to learn professors' definitions of science practices, the Professors' Conceptions of Science Practices Interviews (Appendix K) were conducted in the first week of the program.

Weeks 2-5 of the RET Program

Teachers started their research in week one, and they continued to do it between week two and week five. There was a poster presentation session in the last week of the program where teachers presented their research posters. Therefore, the teachers started to discuss and prepare their posters and between weeks 2 and 5. At the end of the third week, the Teachers' Abilities Engaging in Science Practices Mid-Survey (Appendix D) was conducted. I observed the teachers in the lab during these weeks.

Week six of the RET Program

During week six, the teachers continued working in their research and finalized it with their professors and the graduate students. They also finished and printed their research posters, for that week teachers attended a poster presentation session. They presented their posters with graduate students in this forum. I observed the teachers in the poster presentations (Appendix J). Also, the teachers were interviewed during the poster session (Appendix L: Poster Presentation Interview).

In terms of the data collection instruments, teachers completed the Teachers' Abilities Engaging in Science Practices Post-Survey (Appendix E). Also, in order to find out their understandings of science practices after the program teachers participated in a semi-structured interview (Appendix B: Teachers' Understandings of Science Practices Post-Interview). This interview took approximately a half hour or more. In addition, graduate students were interviewed in order to understand teachers' abilities of science practices (Appendix G: Graduate

Student Perceptions: RET Teachers' Abilities Engaging in Science Practices Interview). During the last week, professors and graduate students also completed the science practices survey in order to see mentors' assessments about the teachers (Appendix F: Faculty/Graduate Student Perceptions: RET Teachers' Abilities Engaging in Science Practices Survey).

Table 4.
Time of the administration of the research instruments

Research Instruments	Pre Program	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Post Program
Appendix A: Teachers' Understandings of Science Practices Pre-Interview								
Appendix C: RET Teachers' Abilities Engaging in Science Practices Pre-Survey								
Appendix H: RET Teacher Observation Protocol								
Appendix D: RET Teachers' Abilities Engaging in Science Practices Mid-Survey								
Appendix B: Teachers' Understandings of Science Practices Post-Interview								
Appendix E: RET Teachers' Abilities Engaging in Science Practices Post-Survey								
Appendix F: Faculty/Graduate Student Perceptions: RET Teachers' Abilities Engaging in Science Practices Survey								
Appendix G: Graduate Student Perceptions: RET Teachers' Abilities Engaging in Science Practices Interview								
Appendix J: Poster Presentation Rubric								
Appendix I: Sources of Different Changes in RET Teachers' Understandings and Abilities Engaging in Science Practices Interview								
Appendix K: Professors' Conceptions of Science Practices Interview								
Appendix L: Poster Presentation Interview								

Post program

After examining the teachers' abilities to engage in science practices and their understandings about science practices, teachers were interviewed again to find the sources of the different changes in their understandings and abilities of science practices (Appendix I: Sources of Different Changes in RET Teachers' Understandings and Abilities Engaging in Science Practices Interview). This interview was conducted after the program and all data were analyzed. Also, Professors' Conceptions of Science Practices Interviews (Appendix K) were conducted with four professors after the program.

Participant Selection

Five preservice and ten inservice teachers were selected by the RET program Principal Investigators from middle and high school science and math teachers in the local school district. The school district has a total enrollment of 193,116 preK-12 students; of whom 22% are African American, 27% are Hispanic, 15.4% are classified as English Language Learners (ELLs), and 48.1% are served through programs for Free/Reduced-cost meals (State Department of Education, 2011).

In addition to the teachers, other participants of the study were the environmental engineering and public health professors and graduate students. There were six professors and eight graduate students in the RET program. Therefore, each teacher worked with a specific professor and graduate mentor in the program. Also, I interviewed two professors from engineering and two professors from the science programs to find out what each science practice means to them. The purpose of this interview was to find out how professors describe and understand each practice. The findings of this interview served as a base when I analyzed the teacher interviews.

The Projects of the Participants

In this study science teachers participated in research projects with professors and graduate students in an environmental engineering RET program. Each teacher worked with a professor and a graduate student in a research group on a specific topic such as the nitrogen cycle, access to clean water, and urban water infrastructure improvement. In the RET program, the teachers can be divided into three groups in terms of the experiences that they had in their projects.

The first group of teachers participated in the projects that included scientific research. Those teachers worked in the labs; identified a research question, hypothesis, or problem; did a literature review; collected and analyzed data; and reported their results.

The second group of teachers worked on a project related to well drilling for urban infrastructure improvement. They primarily worked on how to drill the wells but did not have the opportunity to collect and analyze data. They also presented their posters.

The third group of teachers' projects was related to lesson plan development and implementation. They worked on developing or revising lesson plans that are related to the RET research topics. Those teachers worked in groups, had meetings with the graduate student mentor, and prepared new lesson plans or made revisions on the previous lesson plans.

Data Collection

In this study both qualitative and quantitative data were collected. There were different data sources such as surveys, interviews, observations, and documents (Table 5). Some of these sources were used to collect data several times during and after the RET program in order to better answer the research questions. Therefore, the study achieved data triangulation.

Table 5.

Research questions, participants and research instruments of the study

Research Questions	Participants	Data Collection Instruments
1. How does science teachers' participation in an environmental engineering RET program affect their understandings of science practices?	Teachers	• Appendix A: Teachers' Understandings of Science Practices Pre-Interview • Appendix B: Teachers' Understandings of Science Practices Post-Interview
	Faculty	• Appendix K: Professors' Conceptions of Science Practices Interview
2. How does the participation in the RET program affect science teachers' ability to engage in science practices?	Teachers	• Appendix C: RET Teachers' Abilities Engaging in Science Practices Pre-Survey • Appendix D: RET Teachers' Abilities Engaging in Science Practices Mid-Survey • Appendix E: RET Teachers' Abilities Engaging in Science Practices Post-Survey • Appendix J: Poster Presentation Rubric • Appendix H: RET Teacher Observation Protocol • Appendix L: Poster Presentation Interview
	Faculty/Graduate Students	• Appendix F: Faculty/Graduate Student Perceptions: RET Teachers' Abilities Engaging in Science Practices Survey • Appendix G: Graduate Student Perceptions: RET Teachers' Abilities Engaging in Science Practices Interview
3. What are the sources of differences in the RET teachers' change in their understandings of science practices and ability to engage in science practices?	Teachers	• Appendix I: Sources of Different Changes in RET Teachers' of Science Practices Interview • Appendix B: Teachers' Understandings of Science Practices Post-Interview • Appendix E: RET Teachers' Abilities Engaging in Science Practices Post-Survey • Appendix G: Graduate Student Perceptions: RET Teachers' Abilities Engaging in Science Practices Interview • Appendix H: RET Teacher Observation Protocol

These data sources are:

- Teachers' understandings of science practices pre-interview
- Teachers' understandings of science practices post-interview
- Professors' conceptions of science practices interview
- RET teachers' abilities engaging in science practices pre-survey
- RET teachers' abilities engaging in science practices mid-survey
- RET teachers' abilities engaging in science practices post-survey
- Faculty/graduate student perceptions: RET teachers' abilities engaging in science practices survey
- Graduate student perceptions: RET teachers' abilities engaging in science practices interview
- Poster presentation interview
- Teacher posters
- RET teacher observation
- Sources of different changes in RET teachers' understandings and abilities engaging in science practices interview

The qualitative data were collected from the interviews, observations, and poster presentations. Each data source served a specific research question as explained below. Quantitative data were collected from the science practices surveys. These data sources were determined based on the purpose and research questions of the study.

Research Question 1: How does the participation in the environmental engineering RET program affect science teachers' ability to engage in science practices?

Teachers' abilities engaging in science practices pre, mid and post surveys. The teachers' abilities to engage in science practices were examined by qualitative and quantitative data. Therefore, there were different data sources to answer this research question.

First of all, the Teachers' Abilities Engaging in Science Practices Pre, Mid and Post Surveys (Appendix C, D and E) were conducted at the beginning, in the middle, and at the end of the program, respectively. Fourteen items in the surveys were adopted from Kardash's (2000) research skills survey. Also, four items were added to the survey from the new science education Framework (NRC, 2012). The items that were adopted from Kardash (2000) were also related to the science practices that are in the Framework. The purpose of these surveys was to find out teachers' self-assessments of their level of each science practice. The surveys are Likert-scale and consist of 18 items that describe the science practices needed to engage in scientific research. At the beginning, in the middle, and at the end of the program teachers were asked to what extent they have the ability to engage in science practices using the following choices: Not at all; Very little; Somewhat; Quite a bit; and A great deal. In addition, in the mid survey teachers also were asked to reflect back on what their abilities of science practice were at the beginning of the program. This reflection allowed me to see whether or not there was a difference between teachers' initial thoughts about their abilities of science practices and their ideas in the middle of the program after they had some experience in doing science. Therefore, there were four data points for each teacher in this survey. Also in the post survey, the teachers were asked to write how they gained the science practices and why they think they improved or did not improve in the RET program. If their abilities did not improve, they suggested a reason why not. Therefore, this survey had both quantitative and qualitative data.

Overall, the surveys allowed me to find out to what extent the RET program affected teachers' self-assessments on their abilities to engage in science practices.

Faculty/graduate student perceptions: RET teachers' abilities engaging in science practices survey. This survey was used to assess teachers' abilities to engage in science practices through graduate students' and professors' perceptions (Appendix F). The purpose of this survey was to find out professors' and graduate students' ideas about teachers' abilities of science practices. Therefore, the professors and graduate students were asked to what extent the teachers engage in science practices at the beginning and end of the program. This allowed me both to learn faculty and mentors' perceptions and also to compare teachers' self-evaluations and their mentors' assessments. Therefore, this gave me a better picture of teachers' abilities about doing science than only looking at teachers' self-evaluations. These surveys were also Likert-scale and consist of 18 items that describe the science practices. Professors and graduate students were asked to what extent the teachers have the ability to engage in science practices at the beginning and at the end of the program using the following choices: Not at all; Very little; Somewhat; Quite a bit; and A great deal. This data allowed me to see whether or not there was a difference in teachers' abilities of science practices in the RET program. This survey was conducted after the program. One professor completed the survey for two teachers. The other professors did not accept to complete the survey because they thought they did not have enough interactions with the teachers to assess their abilities.

Graduate student perceptions: RET teachers' abilities engaging in science practices interview. In order to gain deep information about teachers' ability to engage in science practices, semi-structured interviews were conducted with graduate students because they worked with the teachers more closely than the professors (Appendix G). The interviews took approximately one hour and were conducted in a location that was determined by the researcher and the mentors. This interview was conducted after the RET program. The interview had warm-up questions at the beginning and 18 main questions. Each main question was about one specific science practice. In addition to these questions, there were additional follow up questions based on the answers of the mentors. The graduate students were asked how the teachers' ability to engage in science practices changed during the summer and why they thought it improved or stayed the same. These questions allowed me to compare teachers' thoughts about their abilities to engage in science practices with the graduate students' ideas. Because the surveys rely on teachers' self-reports, having additional qualitative data from the graduate students helped me to gain more information on the research questions.

Observations of RET activities. RET teachers were observed in the laboratories, workshops, and field trips. The observations allowed me to evaluate teachers' science practices while they actually performed the research. During the observations an observation protocol (Appendix H) was used. The observations focused on teachers' science practices and researchers' reflective notes. Therefore, during the observations I took notes about each specific science practice. Each teacher was observed individually while they worked with their mentors in the lab. In addition, teachers were observed in their poster presentation and lab tours.

Review of teachers' poster presentations. Each teacher prepared a poster about their research that they presented at the end of the program in a poster presentation. The preparation of the posters began during the first week of the program. In order to better understand teachers' abilities to engage in science practices their posters and poster presentations were also analyzed (Appendix J). The posters allowed me to gain more information about what kind of scientific knowledge teachers included in their presentations. The information that teachers put in the posters provided important information about which science practices teachers focus on more when they report on their research projects. Therefore, this helped me to see the big picture of teachers' ability to engage in science practices.

Teacher interview in the poster presentation. The teachers were interviewed during the poster presentations. The purpose of this semi-structured interview was to find out how they conducted their research and how they communicated their research and results (Appendix L).

Specifically, the teachers' abilities to engage in argument from evidence, construct explanations, and orally communicate the results of research practices were assessed based on their answers in this interview. The interview took about 15 minutes. The rubric which was developed to assess teachers' science practices during the poster presentations was used to rate their abilities.

Research Question 2: How does science teachers' participation in an environmental engineering RET program affect their understandings of science practices?

Teachers' understandings of science practices pre and post interviews. For this research question, the Teachers' Understandings of Science Practices Pre and Post Interviews (Appendix A and B) was conducted. The purpose of these interviews was to find out teachers' understandings of science practices before and after they participated in the environmental engineering RET program. These semi-structured interviews had warm up questions and 18 main questions. Each main question was about one specific science practice and research skill and sought answers about how teachers define and explain each science practice. In these semi-structured interviews, besides the main questions, additional questions were asked based on the answers of the teachers. These interviews took about a half hour or more.

Professors' conceptions of science practices interview. In this interview two professors from the science programs and two professors from the engineering program were asked what each research skill and science practice means to them. The interview included 18 questions (Appendix K). The purpose of this interview was to find out how professors describe each skill and practice. This interview was important because when teachers' understandings of each science practice were evaluated I needed to have the descriptions of these skills and practices to evaluate teachers' understandings of them. After conducting this interview with the professors I found out the characteristics of the skills and practices, and it helped me to find to what extent the teachers understood what each science practice means.

Research Question 3: What are the sources of differences in the RET teachers' change in their understandings of science practices and ability to engage in science practices?

Sources of different changes in ret teachers' understandings of science practices interview. After conducting all the instruments as explained above, the data were analyzed. The changes in teachers' understandings of science practices were determined based on the results of the analysis. The Sources of Different Changes in RET Teachers' Understandings of Science Practices Interview (Appendix I) was conducted to find out the reasons for differences in teachers' science practices changes. In this interview teachers in the case study were asked what reasons they could provide in order to explain the differences in their understandings of each science practice in the RET program. This interview was semi-structured and took approximately 45 minutes.

In addition to this interview as explained above, the Teachers' Understandings of Science Practices Post-Interview (Appendix B), RET Teachers' Abilities Engaging in Science Practices Post-Survey (Appendix E) and Graduate Student Perceptions: RET Teachers' Abilities Engaging in Science Practices Interview (Appendix G) were used to collect data in order to understand what kind of sources affected different changes in teachers' abilities to engage in science practices.

Data Analysis

Quantitative Data Analysis

Teachers' abilities engaging in science practices pre, mid and post surveys. In the science practices survey teachers were asked to what extent they have the ability to engage in science practices using the following choices: Not at all; Very little; Somewhat; Quite a bit; and A great deal. It is a Likert-type instrument consisting of 18 items that describe the science practices. It was conducted as pre, mid, and post surveys at the beginning, in the middle, and at the end of the program, respectively. Each item in the survey was about a specific science practice. In addition, in the mid-survey teachers were asked to reflect back on what their science practice abilities were at the beginning of the program. Therefore, there were four data points for each teacher in this survey.

To find out whether there is a statistical significant difference between the pre, mid and post surveys repeated measures ANOVA was used for each item. In addition, for the items that showed a statistical difference a Tukey test was conducted to find the surveys that significantly differ from each other. Also, partial eta squared effect size was calculated for each item.

Faculty/graduate student perceptions: RET teachers' abilities engaging in science practices survey. In this survey professors and graduate students were asked to what extent the teachers have the ability to engage in science practices using the following choices: Not at all; Very little; Somewhat; Quite a bit; and A great deal. It is a Likert-type instrument consisting of 18 items that describe the science practices needed to engage in scientific research. It was conducted as pre and post surveys at the beginning and at the end of the program, respectively. Each item in the survey was about a specific science practice. Therefore, there were two data points for each professor and graduate student in this survey.

Professor and graduate students' ratings were analyzed by using repeated measures ANOVA. In addition, for the items that showed a statistical difference a Tukey test was conducted to find the surveys that significantly differ from each other. Also, partial eta squared effect size was calculated for each item. This allowed me to see the changes in teachers' abilities to engage in science practices.

Qualitative Data Analysis

Interviews. I transcribed all the interviews, which were coded and analyzed using HyperRESEARCH qualitative analysis software. HyperRESEARCH software allows working with text, enables the researcher to code and retrieve, and conduct analyses of the data. Therefore, the data from all the interviews were transcribed first, and then they were coded and the themes were created. The sequence of analyzing the data is as follows (Figure 3):

1) One of the most obvious ways to analyze the interview data is content analysis. Therefore, in this study the interview data were analyzed based on the content that it includes.

2) The first step to analyze the interview data was reading the data. Therefore, the transcripts/documents were read and reread in order to have a general idea to create the codes and the categories.

3) In order to begin to the systematic indexing process I determined the major topics in the content of the transcripts and listed them separately (Gall, Gall, & Borg, 2007).

4) The next step is the coding of the data. The data were arranged in some ordered fashion such as systematic filing. This means maintaining and indexing the coded data and sorting data into coded classifications.

5) Based on the coding of the data, specific themes were created in order to classify the coding.

6) The naturally occurring classes of things, persons, and events and important characteristics of these terms were sought by the researcher in order to find out the similarities and differences of the patterns in the data. These patterns were looked at systematically.

7) The codes, categories, and patterns were interpreted by examining and comparing strategies based on the information collected (Berg, 2009; Miles & Huberman, 1994).

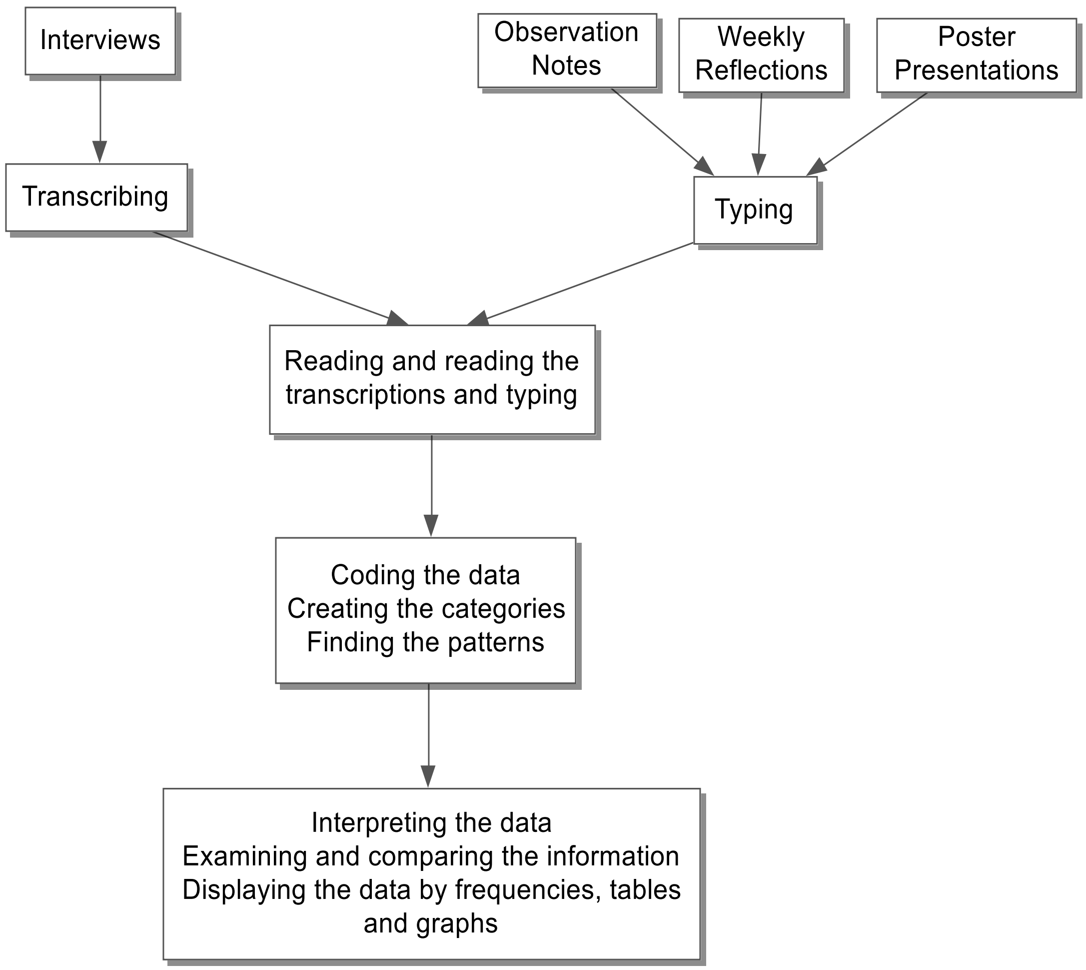

Figure 3. Qualitative data analysis procedure of the research adapted from components of data analysis interactive model (Miles & Huberman, 1994).

Observation notes from the RET activities and teacher posters. Observations and poster presentations also were analyzed. The purpose of using these data instruments was to find out teachers' understandings and abilities to engage in science practices. Therefore, science practices were used as a theme for the analysis of these documents. First of all, I typed the observation notes. In order to analyze the data in the observations the procedure that was used for the analysis of interviews (Figure 3) was followed. Therefore, all the data were read and reread in order to comprehend and create the codes and the categories of the information. The observation notes were coded based on the science practices to find out more information about teachers' abilities.

Observation notes were analyzed using HyperRESEARCH software. The indicator sentences or phrases in these documents were coded based on the practices, and the data were interpreted by examining and comparing the information found in the documents. These data instruments allowed me to gain more deeply information about the extent to which the teachers were able to engage in science practices.

The teachers' posters, poster presentations, and the answers they provided during the poster presentation interview were evaluated using the rubric containing the criteria for each expected part of the practices (Appendix J).

Trustworthiness of the Study: Validity and Reliability

Joppe (2000) defines validity as "the extent to which the research truly measures that which it was intended to measure or how truthful the research results are" (p.1). In quantitative research validity refers to "the extent to which the research uses methods and procedures that ensure a high degree of research quality and rigor" (Gall, Gall, Borg, 2007, p.657). The extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability, and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable (Joppe, 2000).

Guba and Lincoln (1981 & 1982) used the concept of “trustworthiness,” instead of reliability and validity in qualitative research. Trustworthiness consists of four aspects: credibility, transferability, dependability, and confirmability. To demonstrate qualitative rigor, researchers can use specific strategies such as member checks, audit trail, peer debriefing, and triangulation (Guba & Lincoln, 1981; Guba & Lincoln, 1982).

When researchers establish internal validity this means that they seek to ensure that their study measures what is actually intended (Shenton, 2004). In qualitative research, credibility (internal validity) is one of the most important criteria in order to establish the trustworthiness of the study (Lincoln & Guba, 1985).

For Lincoln & Guba (2000), “qualitative rigor is community consent and defensible reasoning based on interpretative rigor” (p. 170). Anfara, Brown, and Mangione (2002) summarized the techniques that Lincoln and Guba (1985) proposed to establish trustworthiness of the research. In this research, those strategies were used to establish the trustworthiness.

To establish the credibility (internal validity) of the qualitative data prolonged engagement, peer debriefing, data triangulation, member checks, and time sampling strategies were employed (Anfara, Brown, & Mangione, 2002). This research lasted six weeks and I engaged in all parts of the study in which the teachers engaged. The teachers were observed for a long time in order to meet the goal of prolonged engagement in the lab, in the field, and at their poster presentations. Peer debriefing strategy was also employed by discussing all steps of the research with the other science educators. In general, the peer debriefing took place in the weekly research group meetings with a science education professor and PhD students. The discussions included the design of the study, data collection, analysis, and data interpretation. “Triangulation is the use of multiple data collection methods, data sources, analysis, or theories as corroborative evidence for the validity of qualitative research findings" (Gall, Gall, & Borg, 2007, p. 657). The study also met this criterion for triangulation through multiple methods of data collection such as teacher, professor, and graduate student interviews; teacher and graduate student surveys; observations; and presentations. Therefore, using different kinds of data collection methods in this study allowed the research to meet the qualifications of data triangulation. Member checks are one of the most important strategies to ensure credibility in research. For this strategy, after all the data were analyzed, the teachers in the case study were asked to read the transcriptions of the pre and post interviews, and then I expressed my interpretation of their answers. I asked them what they thought about my interpretations and whether they agreed or disagreed. The purpose of the member check was to determine whether the participants considered that their words matched what they actually intended and to see whether they agreed with my interpretations. The teachers expressed that they agreed with all my interpretations. Therefore, this allowed me to have an accurate articulation of the answers of the participants. Time sampling strategy was also met by interviewing and surveying the participants in the research several times, and observing on different days of the week and in different places such as labs, in the field, and at the presentations.

To establish the dependability (reliability) of the qualitative data, in addition to data triangulation, peer examination was conducted (Anfara, Brown, and Mangione, 2002). In the peer examination, the data was discussed with other researchers to recheck the accuracy of the codes in the analysis. To establish this criteria, another science educator coded one of the science practices (this science practice was to analyze numerical data) that included all the teachers' answers in the interview. This science educator was given the text and the codebook that included the definitions and explanations of the codes. Before that, I trained this science educator about how the coding needed to be done based on the definitions of the codes and text. I showed her examples of coding by using the codebook and text of another science practice (developing and using models), and I explained how the coding should be done. Inter-coder reliability was determined to find out to what extent the other coder and I agreed on the coding of the content. There was 100% agreement between the other science educator and me on all the codes.

Transferability (external validity) means the extent to which the results of one study can be used in another study to have similar results. Since in qualitative studies the sample size is generally small, it is not possible to demonstrate the findings and results are applicable to other situations. However, it is the responsibility of the researcher to provide enough detail about the research to enable the reader to transfer the study (Anfara, Brown, & Mangione, 2002). Therefore, in this study I provided enough details about the each part of the research in order to enable the reader to have all the information. Finally, the study used the purposive sampling method to establish the transferability of the study (Anfara, Brown, & Mangione, 2002). The sample of the study was selected based on the research questions and purposes.

In addition to data triangulation, practice reflexivity (Anfara, Brown, & Mangione, 2002) was used through keeping a research journal to establish the confirmability of the study. In this way, I recorded my experiences and emotions that emerged during the research.

Content validity was used to establish the validity of the quantitative data. Content validity is "the extent to which the items in a test represent the domain of content that the test is designed to measure" (Gall, Gall, & Borg, 2007, p. 636). First of all, the 14 items in the survey were adopted form Kardash (2000) and was a validated instrument. I also established the content and internal validity again by adding different items. In addition to these 14 original items, I also added eight science practices that are in the new science education Framework. I then asked two professors what they thought about the content and whether it represented all the science practices. Based on their recommendations we decided to remove four items because they were very similar to other items in the survey. After this step, they were agreed on all the items. In addition, the English and wording of the questions were revised based on their recommendations. To establish the internal validity of the surveys, they were pilot tested with the target population, but with different teachers in the previous RET program in 2012.

Test-retest reliability was used to establish the reliability of the Teachers' Abilities Engaging in Science Practices Pre Survey. Test-retest reliability "is an approach to estimating test score reliability that involves examination of the occasion of test administration" (Gall, Gall, & Borg, 2007, p. 201). To determine the test-retest reliability, all the teachers completed the pre survey two times before the RET program began. The first administration of the survey was done approximately one week before the program, and the second administration was done on the first day of the program before the teachers' welcome meeting. I calculated the Pearson product moment correlation coefficient (r) for each item. The analysis indicated there was a high reliability ranging from 0.53 to 0.84 for the items understand the importance of controls, analyze numerical data, interpret data, write a scientific report of research, think independently, develop and use models, use mathematics and computational thinking, identify a specific question for investigation, formulate a research hypothesis, reformulate the original hypothesis, relate results to the bigger picture, constructing explanations and engaging in argument from evidence practices. The Pearson correlation coefficient showed a moderate reliability for the items design an experiment ($r = 0.35$) and orally communicate construct explanations ($r = 0.48$). For the overall survey, the Pearson correlation coefficient was found to be 0.78. This means there is a high correlation between the two implementations of the survey.

Advantages and Disadvantages

One of the advantages of this study was the use of mixed methods research design. In this way, the study was built based on the strength of both quantitative and qualitative research methods and provided more insightful findings than either of the study designs alone. Therefore, this study provided a complete picture of the teachers' understandings and abilities of science practices. Because the mixed methods study design requires the researcher to collect both qualitative and quantitative data it takes more time to collect and analyze the data and also requires being knowledgeable about both research designs.

Ethical Considerations

In this study, I had the permission of the teachers, professors, and graduate students to participate in the research. The research process did not cause any physical or emotional harm to the participants. Also, I made efforts to reduce personal biases and opinions that otherwise would get in the way of this research. All efforts were made to keep the data anonymous.

The participants of the research were selected based on what would most benefit this research. Therefore, when selecting the participants ethical issues also were considered. This research involved human subjects, therefore IRB approval was obtained. This means this research was approved by an ethics review committee to make sure the researcher is not violating any of the above considerations. In terms of the reporting the results of the research, I accurately presented what was observed or what was told during the study. Therefore, the results of the research were not changed for any reason, and they were accurately reported.

It is also important to note that one of the faculty members on the dissertation committee was also involved in the program. The professor served as a mentor and worked with one of the teachers during the RET program. I made efforts not to be affected by this situation. I established the reliability of the results and the interpretation by peer debriefing, peer examination and member checks to manage the subjectivity and to have correct interpretations. Therefore, having this professor both on the committee and in the program did not affect my interpretation of the results and did not cause any issue related to ethical considerations. The other mentors in the study were graduate students and professors from engineering and science programs, and their participation did not cause ethical issues.

In addition, I was also the research assistant and one of the evaluators of the RET program. Therefore I had financial support from this project. I want to emphasize that my initial interest in my PhD education was related to the research, inquiry, and pre- and in-service teachers. My interest was in line with the RET program since it provides research experiences for teachers. My purpose in this study was to find out teachers' understandings and abilities of the science practices after they had a research experience. I thought that finding out teachers' understandings of the science practices was important because the new science education Framework (NRC, 2012) published the science practices. The RET program provided me opportunities to find both teachers' understandings and also how a research experience affects their understandings. Therefore, I wanted to work with the teachers in this RET program. That means the financial support I received did not affect my interest in the research, and did not affect my research methods, findings, or interpretation.

CHAPTER FOUR:

ANALYSIS AND FINDINGS

Introduction

The purposes of this study are to investigate science teachers' understandings of science practices before and after they participated in an environmental engineering RET program, to identify how teachers' participation in the RET program affected their ability to engage in science practices, and to investigate the sources of differences in teachers' understandings of science practices and abilities to engage in science practices. Different data collection instruments were used to reach these goals and the results are presented in this chapter.

The research questions of this study are;

1. How does the participation in the RET program affect science teachers' ability to engage in science practices?
2. How does science teachers' participation in an environmental engineering RET program affect their understandings of science practices?
3. What are the sources of differences in RET teachers' changes in their understandings of science practices and abilities to engage in science practices?

In this chapter, I provide the answers to the three research questions and present the cases of two teachers. Before explaining teachers' understandings of science practices, I present those two teachers' background information, what they experienced in the RET program, the results of how teachers' participation in the RET program affected their abilities to engage in science practices (research question one), as well as the analysis of individual cases of those two teachers, followed by teachers' understandings of science practices (research question two), respectively. The purpose of that order is to make better connections between the teachers' backgrounds, what they experienced and learned in the RET program in terms of engaging in science practices, and how those features affected their understandings of science practices. At the end, I present what might be the reasons for the different changes in teachers' abilities and understandings (research question three).

Individual Cases: Teachers' Background Information and Their Experiences in the RET Program

Two teachers were selected as cases based on their experiences and also whether their abilities and understandings of science practices improved in the RET program. The analysis indicates that they should be presented as cases to represent the teachers in terms of their experiences and improvements in the program. The first case, Ivette, showed an increase in both her understandings and abilities of science practices. The second case, Ashlynn, did not show much increase in either criterion.

Ivette's Case

Ivette, a Hispanic female, was a preservice teacher in secondary science education at the time of the study; she also tutored reading and math for ESOL students. She started her BSc in chemistry in her home country, and during that time she had the opportunity to work as a middle school teacher for six months. She then moved to the US and started to work in a daycare center. In the pre-interview, she stated that even though it is not her preferable age to teach, that job affected her decision to move into education. As a result, she decided to apply to the secondary science chemistry education program in a Southeastern U.S. university. Ivette has not participated in an RET program before, and the only research experience she had was in high school. She had a grant when she was in grade eleven and worked with a doctor in one of the U.S. universities. That research was about fruit flies, and her primary job was to remove the ovaries of the fruit flies for the summer. She said she enjoyed the experience a lot and it helped her to improve her English.

Ivette worked with a graduate student and a professor in environmental engineering, and during the program participated in the research group meetings. Her research group was working on aquaculture. They investigated how to remove the off-flavor compounds in the fish tanks that accumulate in the fish. These compounds cause quality problems and increased water usage to clean the fish before they are sold to the public. Her graduate student asked her to join their Dropbox documents group, so she was exposed to a lot of the literature they had to read in order to know what they were working on and what other people have done about it. They then discussed a couple of experiments that they needed to perform for the research. After discussing this with the graduate student she decided on her research questions: how the usage or storage affects the fish feed quality (it is related to the quality standards of the feed), and what the effects are on water quality in a feed for the recirculating aquaculture system. In order to answer those research questions, Ivette was in charge of running two different experiments. One was the storage experiment, where they wanted to determine how the feed in the aquaculture system that they have in the lab is affected by storage time in the refrigerator. The other experiment was how the quality of the feed changes over time when it has been used for the aquaculture system in the lab. She designed the experiments with the graduate student mentor. In the beginning of the RET program, the graduate student taught her how to do the basic measurements. Her research did not include a control, but she discussed with her graduate student mentor whether or not they needed to use a control in their research. She performed various water quality measurements including pH, dissolved oxygen, ammonia, nitrate, nitrite, and conductivity. She also prepared feeds, solutions, and dilutions for the research. The graduate student gave her a quick Excel course and explained how she could analyze the data. By using Excel, Ivette analyzed averages of the data to determine if they were increasing or decreasing or if they stayed the same over time; she also calculated the standard deviations to see if they were different; and she calculated the figures to see the daily changes. Every time they did the experiment, Ivette sat down and discussed with the graduate student what was happening and what they were seeing in the experiments. She presented her research two times in the program. The first one was in the middle of the program, which she presented in the lab tours. The second presentation was at the end of the program, where she prepared a poster and presented it at the NSF Research Day.

Ivette's research group was tightly organized. In tightly organized groups the interactions between the members are very important. In the tight organization, although the professors play an important role in developing the groups and facilitating interactions among the students, the interactions between the members that take place on a continuing basis are more important (Feldman, Divoll, & Rogan-Klyve, 2009). In Ivette's group, the center of their action was the laboratory, and their professor played an important role in developing the interactions between the graduate student and Ivette. Therefore, Ivette basically had two mentors; her professor and the graduate student. They conducted weekly group meetings and discussed their research. Also, Ivette had discussions with her graduate student mentor on a daily basis.

Ashlynn's Case

Ashlynn, a White female, went to Aqua College for marine science. She worked as a resident camp counselor and thinks that job gave her the opportunity to be always outside in nature with students and teaching them about the environment. In addition, she worked in an environmental organization and most recently spent four years at a small aquarium teaching environmental science and marine science. She had not participated in an RET program before. Both in and out of college, she worked for a dolphin research project and performed research through a marine lab working with dolphins and fish. In the pre-interview, she said most of her research experience was in-field research. For the dolphin project, she conducted behavioral studies of the dolphins, such as their feeding behaviors, their groups and who they were with, and mating behaviors. She analyzed the data and presented the results at a conference. In her other research, she would performed dolphin predator-prey studies, going out in a boat to collect fish and study features such as size and type of fish. She said she worked like an intern in those projects, because she did not identify the research questions but assisted the researchers. She said she loved the field research, so that was why she selected the marine science research; playing with dolphins and fish in the water and getting to do all the fun hands-on stuff were the exciting parts. She said she also enjoyed the data collection and analysis part of the research.

In the RET program, Ashlynn's research group included the professor, her graduate student mentor, and an in-service teacher who was also selected for the RET program. Ashlynn did not have much connection with the professor because she was out of the country. The graduate students' research project she participated in was about looking at aquaponics, which is the combination of aquaculture and hydroponics. It is a recirculating system, waste products from the fish are treated using a bioreactor that transforms the ammonia to nitrate that acts as a fertilizer for the plants. The purpose of the part of the research part that Ashlynn worked on was to observe the transformations of nitrogen during the start-up phase of an aquaponic system. Her research question was how long it takes to produce an effective nitrogen cycle from the begining. She did not have to develop her own question because the graduate student gave her the question directly. In terms of the literature review, she was not given much information; she only reviewed a few articles for her poster. In the program, Ashlynn did not really design an experiment because the graduate student had her project and from that they worked on water quality. Some controls she had to look at were adding the fish with the same amount of ingredients and making sure that the samples were taken at same time every day from the same locations that she tested. Her data collection was to test the samples of water for nitrate, total nitrogen, phosphate, dissolved oxygen, total phosphorous, chemical oxygen demand, ammonia, and reactive phosphate. She was not involved in the data analysis part of the project because she did not have much interest in analyzing the data and left that part more to the other RET teacher with whom she worked. Ashlynn presented her research in the lab tours, which were in the middle of the program. She prepared a poster with the in-service teacher but could not participate in the poster presentation session in the NSF Research Day because she had to participate in a professional development for her student teaching internship.

Ashlynn participated in a loosely organized research group. The center of action in the loosely organized research groups were the professors. In this structure, student-student interactions are very few because students' connections to the group were through the professors. Therefore, they spend more time with the professors than with the other students in the group (Feldman, Divoll, & Rogan-Klyve, 2009). This suggests that in loosely organized groups the interactions among the all the group members are not strong. In Ashlynn's case, her professor was out of the country; therefore, she did not have the opportunity to have strong interactions with her professor. However, her relationship with her graduate student mentor was similar to the relationship between a professor and student in a loosely organized group. She mostly followed the directions of the graduate student. Therefore, she had less support from her professor.

Below, first I present the results of how teachers' participation in the RET program affected their abilities to engage in science practices (research question one), as well as the analysis of individual cases of those two teachers, followed by teachers' understandings of science practices (research question two), respectively. That allowed me to make better connections between teachers' backgrounds, what they experienced and learned in the RET program in terms of engaging in science practices, and how those features affected their understandings of science practices. Then, I present what might be the reasons that cause different changes in teachers' abilities and understandings (research question 3).

Research Question 1: How does the Participation in the RET Program Affect Science Teachers' Abilities to Engage in Science Practices?

In this part, I present the analysis of different data collection instruments including teachers' abilities of engaging in science practices pre-, mid- and post- surveys; graduate student surveys; and poster presentations. The analysis allowed me to synthesize the answers of all the teachers and to find the similarities and differences between the cases. Also, this method helped me to provide more explanations about the RET program and its effects on teachers' abilities to engage in science practices. In addition, the results of two teachers' case studies are presented based on the analysis of the same research instruments, as well as making connections with my observations, and the teacher and graduate student interviews.

The Results of All Teachers

Below, I present the analysis and results of all the teachers.

Teacher pre-, mid-, and post-survey results. The teachers were administered a self-reported survey in the beginning, in the middle, and at the end of the program to find out their abilities to engage in science practices. In the pre-survey, they were asked to what extent they were able to engage in science practices in the beginning of the program. In the mid-survey, first they were asked to what extent they were able to engage in each science practice in the middle of the program (Mid-Now); and then they were asked to reflect back on what their abilities of science practices were at the beginning of the program (Mid-Initial). In the post survey, they were asked to what extent they were able to engage in each science practice at the end of the program. The survey was a 5-point Likert scale type and consisted of 18 items that are related to the science practices. In order to determine if there is a statistically significant difference between the means of the pre-, mid-, and post-surveys repeated measures ANOVA analyses were conducted for each item by using SAS quantitative data analysis program. In addition, for the items that showed a statistically significant differences in ANOVA, a Tukey test was used to make all pairwise comparisons between the surveys in order to see which pairs have the significant difference for the means of each item.

The analysis indicated that, in general, the mean values of each item increased from pre- to mid-now and to post-surveys (Table 6 and 7). The ANOVA analysis indicated that there is a statistically significant difference for the means of eleven items in pre-, mid-now and post-surveys (Table 8). These items are the ability to make use of the primary literature, identify a specific question, formulate a research hypothesis, design an experiment, interpret data, reformulate the original hypothesis, relate results to the bigger picture, orally communicate the results of research, write a scientific report, think independently, develop and use models, use mathematics and computational thinking, constructing explanations, and engaging in argument from evidence ($p<0.05$). The means of the items, understand the importance of controls, make observations and collect data, and analyze numerical data, did not indicate a statistically significant difference between pre-, mid-now and post-surveys ($p>0.05$). The analysis also indicated that there is no interaction effect. Partial eta squared (η_p^2) was used to report the group differences. A small effect was found for the item "to understand the importance of control" (η_p^2 = 0.006) and a large effect was found for all the other items because η_p^2 is greater than 0.14 (Cohen, 1988). For the items that were statistically different, a Tukey test was used to make all pairwise comparisons between pre-, mid-now and post-surveys in order to see which pair or pairs have the significant difference for the means of those items (Table 9). For the means of items to identify a specific question, formulate a research hypothesis, interpret data, reformulate the original hypothesis, develop and use models and engaging in argument from evidence statistically significant differences were found only between pre- and post-surveys. The means of the items make use of the primary scientific research literature, design an experiment, relate results to the bigger picture, think independently, use mathematics and computational thinking, and constructing explanations indicated a statistically significant difference between (a) pre- and post-, and (b) pre- and mid-now surveys. Orally communicate the results of research and write a scientific report indicated a statistically significant difference between (a) pre- and post-, and (b) mid-now and post-surveys. Understand fundamental concepts of research practice indicated no pairwise differences between means that are statistically different from each other.

In addition to the analysis of pre-, mid-now and post-surveys; mid-initial, mid-now and post-surveys were also analyzed. As is mentioned above, in the pre-survey the teachers were asked to what extent they were able to engage in science practices at the beginning of the program, and in the mid-now survey they were asked to reflect back on what their abilities of science practices were at the beginning of the program. In general, the mean values in the mid-now survey for each item were lower than the mean values in the pre-survey. Therefore, the purpose of this analysis was to see whether they provided different or similar results in the comparison of the teachers' abilities at the beginning, in the middle, and at the end of the program.

Table 6.

Means and standard deviations in teacher pre, mid-now and post surveys

	N	Pre	Mid-Now	Post
		Mean (STD)	Mean (STD)	Mean (STD)
Understand fundamental concepts	11	3.91 (0.54)	4.09 (0.70)	4.36 (0.81)
Make use of primary literature	11	3.64 (0.67)	4.18 (0.60)	4.45 (0.52)
Identify a specific question	11	3.45 (0.82)	4.09 (0.94)	4.45 (0.93)
Formulate a research hypothesis	11	3.45 (0.82)	3.91 (0.94)	4.45 (0.69)
Design an experiment	11	3.18 (0.60)	3.91 (0.94)	4.27 (0.79)
Understand the controls	11	4.09 (1.04)	4.09 (0.83)	4.36 (0.67)
Make observations and collect data	11	3.82 (0.75)	4.18 (0.75)	4.45 (0.69)
Analyze numerical data	10	3.5 (0.92)	3.9 (1.04)	4.1 (0.88)
Interpret data	11	3.45 (1.04)	3.82 (1.08)	4.27 (0.79)
Reformulate the original hypothesis	10	3.3 (1.06)	3.8 (0.79)	4.3 (0.82)
Relate results to the bigger picture	11	3.55 (0.69)	4.36 (0.81)	4.64 (0.50)
Orally communicate the results	11	3.45 (0.69)	4 (0.89)	4.64 (0.67)
Write a scientific report	10	3.5 (0.85)	3.7 (0.95)	4.2 (0.79)
Think independently	11	3.55 (0.69)	4 (0.77)	4.36 (0.50)
Develop and use models	11	3.55 (0.82)	4 (0.89)	4.45 (0.69)
Mathematics-computational thinking	11	3.36 (0.81)	3.91 (1.14)	3.91 (1.04)
Constructing explanations	11	3.27 (1.01)	4 (0.77)	4.27 (0.65)
Engaging in argument from evidence	11	3.45 (0.93)	3.91 (0.94)	4.09 (0.70)

Table 7.
Mean and standard deviations in pre, mid-now and post surveys of each group

Item	Group	N	Pre		Mid-now		Post	
			Mean	STD	Mean	STD	Mean	STD
Understand fundamental concepts	Research	7	4.14	0.38	3.86	0.69	4.43	0.79
	Well-drilling	2	3	0	4	0	3.5	0.71
	Lesson planning	2	4	0	5	0	5	0
Make use of primary literature	Research	7	3.86	0.69	4.0	0.58	4.43	0.53
	Well-drilling	2	3	0	4	0	4	0
	Lesson planning	2	3.5	0.71	5	0	5	0
Identify a specific question	Research	7	3.71	0.76	4.14	0.9	4.71	0.49
	Well-drilling	2	2.5	0.71	3	0	3	1.41
	Lesson planning	2	3.5	0.71	5	0	5	0
Formulate a research hypothesis	Research	7	3.71	0.76	3.86	0.9	4.57	0.53
	Well-drilling	2	2.5	0.71	3	0	3.5	0.71
	Lesson planning	2	3.5	0.71	5	0	5	0
Design an experiment	Research	7	3.29	0.49	3.86	0.9	4.43	0.79
	Well-drilling	2	2.5	0.71	3	0	3.5	0.71
	Lesson planning	2	3.5	0.71	5	0	4.5	0.71
Understand the controls	Research	7	3.86	1.07	4.0	0.82	4.57	0.53
	Well-drilling	2	4	1.41	3.5	0.71	3.5	0.71
	Lesson planning	2	5	0	5	0	4.5	0.71
Make observations and collect data	Research	7	3.86	0.69	4.14	0.69	4.71	0.49
	Well-drilling	2	3	0	3	0.71	3.5	0.71
	Lesson planning	2	4.5	0.71	5	0	4.5	0.71
Analyze numerical data	Research	6	3.5	0.84	3.83	1.17	4.17	0.98
	Well-drilling	2	2.5	0.71	3	0	3.5	0.71
	Lesson planning	2	4.5	0.71	5	0	4.5	0.71
Interpret data	Research	7	3.71	0.76	3.71	1.11	4.43	0.79
	Well-drilling	2	2	1.41	3	0	3.5	0.71
	Lesson planning	2	4	0	5	0	4.5	0.71
Reformulate the original hypothesis	Research	6	3.57	0.79	3.86	0.69	4.43	0.79
	Well-drilling	2	2	1.41	3	0	3.5	0.71
	Lesson planning	2	4		5		5	
Relate results to the bigger picture	Research	7	3.57	0.79	4.29	0.95	4.71	0.49
	Well-drilling	2	3	0	4	0	4	0
	Lesson planning	2	4	0	5	0	5	0
Orally communicate the results	Research	7	3.43	0.79	3.71	0.95	4.57	0.79
	Well-drilling	2	3	0	4	0	4.5	0.71
	Lesson planning	2	4	0	5	0	5	0
Write a scientific report	Research	6	3.67	0.82	3.5	0.84	4.33	0.82
	Well-drilling	2	2.5	0.71	3	0	3.5	0.71
	Lesson planning	2	4	0	5	0	4.5	0.71
Think independently	Research	7	3.57	0.79	3.86	0.69	4.43	0.53
	Well-drilling	2	3	0	3.5	0.71	4	0
	Lesson planning	2	4	0	5	0	4.5	0.71
Develop and use models	Research	7	3.71	0.76	3.86	0.9	4.57	0.53
	Well-drilling	2	2.5	0.71	3.5	0.71	3.5	0.71
	Lesson planning	2	4	0	5	0	5	0
Mathematics-computational thinking	Research	7	3.57	0.79	3.86	1.07	4.14	0.9
	Well-drilling	2	2.5	0.71	3	1.41	2.5	0.71
	Lesson planning	2	3.5	0.71	5	0	4.5	0.71
Constructing explanations	Research	7	3.43	0.79	3.86	0.69	4.43	0.53
	Well-drilling	2	2	1.41	3.5	0.71	3.5	0.71
	Lesson planning	2	4	0	5	0	4.5	0.71
Engaging in argument from evidence	Research	7	3.43	0.79	3.57	0.98	4	0.82
	Well-drilling	2	2.5	0.71	4	0	4	0
	Lesson planning	2	4.5	0.71	5	0	4.5	0.71

Table 8.
Results of repeated measures ANOVA for teacher pre, mid-now, post surveys

Item	Source	df	Sum of Squares	Mean Squares	*F*	p	η_p^2
Understand fundamental concepts	Time	2	1.789	0.894	4.49	0.0284*	0.36
	Time*Group	4	2.325	0.581	2.91	0.0548	
	Error	16	3.19	0.199			
Make use of primary literature	Time	2	4.842	2.421	12.52	0.0005*	0.61
	Time*Group	4	1.753	0.438	2.27	0.1074	
	Error	16	3.095	0.193			
Identify a specific question	Time	2	4.44	2.22	4.97	0.0209*	0.38
	Time*Group	4	1.221	0.305	0.68	0.6135	
	Error	16	7.143	0.446			
Formulate a research hypothesis	Time	2	5.057	2.528	7.08	0.0063*	0.47
	Time*Group	4	1.437	0.359	1.01	0.4333	
	Error	16	5.714	0.357			
Design an experiment	Time	2	4.905	2.452	8.24	0.0035*	0.51
	Time*Group	4	1.117	0.279	0.94	0.4670	
	Error	16	4.761	0.298			
Understand the controls	Time	2	0.063	0.031	0.05	0.9514	0.006
	Time*Group	4	2.121	0.53	0.85	0.5150	
	Error	16	10	0.625			
Make observations and collect data	Time	2	1.021	0.51	1.53	0.2463	0.16
	Time*Group	4	1.091	0.273	0.82	0.5322	
	Error	16	5.333	0.333			
Analyze numerical data	Time	2	1.333	0.667	1.75	0.2097	0.20
	Time*Group	4	0.8	0.2	0.53	0.7192	
	Error	14	5.333	0.381			
Interpret data	Time	2	3.464	1.732	4.41	0.0298*	0.36
	Time*Group	4	2.017	0.504	1.28	0.3176	
	Error	16	6.286	0.393			
Reformulate the original hypothesis	Time	2	3.58	1.79	5.01	0.0228*	0.42
	Time*Group	4	0.667	0.167	0.47	0.7593	
	Error	14	5	0.357			
Relate results to the bigger picture	Time	2	2.083	2.542	5.55	0.0148*	0.22
	Time*Group	4	0.242	0.061	0.13	0.9683	
	Error	16	7.333	0.458			
Orally communicate the results	Time	2	5.932	2.966	10.07	0.0015*	0.56
	Time*Group	4	0.922	0.231	0.78	0.5530	
	Error	16	4.714	0.295			
Write a scientific report	Time	2	2.048	1.024	6.14	0.0122*	0.47
	Time*Group	4	1.733	0.433	2.60	0.0816	
	Error	14	2.333	0.167			
Think independently	Time	2	2.646	1.323	10.58	0.0012*	0.57
	Time*Group	4	0.97	0.242	1.94	0.1529	
	Error	16	2	0.125			
Develop and use models	Time	2	3.87	1.935	7.07	0.0063*	0.47
	Time*Group	4	1.074	0.269	0.98	0.4459	
	Error	16	4.381	0.274			
Mathematics-computational thinking	Time	2	2.393	1.196	5.43	0.0158*	0.40
	Time*Group	4	1.628	0.407	1.85	0.1691	
	Error	16	3.524	0.22			
Constructing explanations	Time	2	5.128	2.564	9.16	0.0022*	0.53
	Time*Group	4	1.645	0.411	1.47	0.2576	
	Error	16	4.476	0.28			
Engaging in argument from evidence	Time	2	2.592	1.296	5.06	0.0198*	0.39
	Time*Group	4	2.208	0.552	2.16	0.1207	
	Error	16	4.095	0.256			

Note. *The mean difference is significant at 0.05 level.

Table 9.

Tukey results for teacher pre, mid-now and post surveys

Item	Survey (I)	Survey (J)	Mean Difference (I-J)	Minimum Difference for Significance
Understand fundamental concepts	Post	Pre	0.4545	
		Mid-Now	0.2727	0.4908
	Mid-Now	Pre	0.1818	
Make use of primary literature	Post	Pre	0.8181*	
		Mid-Now	0.2727	0.4834
	Mid-Now	Pre	0.5455*	
Identify a specific question	Post	Pre	1*	
		Mid-Now	0.3636	0.7348
	Mid-Now	Pre	0.6364	
Formulate a research hypothesis	Post	Pre	1*	
		Mid-Now	0.5455	0.6574
	Mid-Now	Pre	0.45455	
Design an experiment	Post	Pre	1.0909*	
		Mid-Now	0.3636	0.6006
	Mid-Now	Pre	0.7273*	
Interpret data	Post	Pre	0.8182*	
		Mid-Now	0.4545	0.6897
	Mid-Now	Pre	0.3636	
Reformulate the original hypothesis	Post	Pre	1*	
		Mid-Now	0.5	0.6574
	Mid-Now	Pre	0.5	
Relate results to the bigger picture	Post	Pre	1.0909*	
		Mid-Now	0.2727	0.7446
	Mid-Now	Pre	0.8181*	
Orally communicate the results	Post	Pre	1.1818*	
		Mid-Now	0.6364*	0.5976
	Mid-Now	Pre	0.5455	
Write a scientific report	Post	Pre	0.7*	
		Mid-Now	0.5*	0.4496
	Mid-Now	Pre	0.2	
Think independently	Post	Pre	0.8182*	
		Mid-Now	0.3636	0.3890
	Mid-Now	Pre	0.4545*	
Develop and use models	Post	Pre	0.9091*	
		Mid-Now	0.4545	0.5759
	Mid-Now	Pre	0.4545	
Mathematics-computational thinking	Post	Pre	0.5455*	
		Mid-Now	0	0.5160
	Mid-Now	Pre	0.5455*	
Constructing explanations	Post	Pre	1*	
		Mid-Now	0.2727	0.5822
	Mid-Now	Pre	0.7273*	
Engaging in argument from evidence	Post	Pre	0.6364*	
		Mid-Now	0.1818	
	Mid-Now	Pre	0.5455	0.5567

Note. *The mean difference is significant at 0.05 level.

The means of all items increased from the mid-initial to mid-now and to post-surveys (Table 10 and 11). The ANOVA analysis indicated that there is a statistically significant difference for the means of eight science practices (Table 12). These items are make use of primary literature, design an experiment, relate results to the bigger picture, orally communicate the results of research, write a scientific report, think independently about research area, develop and use models, and engaging in argument from evidence. Partial eta squared (η_p^2) was used to report the effect size. While the item understand the importance of controls indicated a medium effect size ($\eta_p^2 = 0.12$), very large effect is found for all items because η_p^2 greater than 0.14 (Cohen, 1988).

For the items that were statistically different in ANOVA, a Tukey test was used to make all pairwise comparisons between mid-initial, mid-now and post-surveys in order to see which pair or pairs have the significant difference for the means of those items. The Tukey results are presented in Table 13. The statistically significant differences were between (a) mid-initial and post-, (b) mid-now and post-, and (c) mid-initial- and mid-now surveys for the means of items orally communicate the results of the research. Also, the means of the items make use of the primary literature, design an experiment and think independently practice indicated statistically significant differences between (a) mid-initial- and post-, and (b) mid-initial- and mid-now surveys. In addition, statistically significant differences were between (a) mid-initial and post-, and (b) mid-now and post-surveys for the means of the item write a scientific report of research. And the means of the items that showed a statistically significant difference only between mid-initial and post-surveys are relate results to the bigger picture, develop and use models, and engaging in argument from evidence.

Table 10.
Means and standard deviations in teacher mid-initial, mid-now and post surveys

	N	Mid-initial Mean (STD)	Mid-Now Mean (STD)	Post Mean (STD)
Understand fundamental concepts	11	3.36 (1.12)	4.07 (0.73)	4.25 (0.87)
Make use of primary literature	11	3.36 (1.12)	4.14 (0.66)	4.42 (0.51)
Identify a specific question	11	3.27 (1.19)	4.07 (0.92)	4.5 (0.90)
Formulate a research hypothesis	11	3.36 (1.29)	3.93 (0.92)	4.42 (0.67)
Design an experiment	11	3.27 (0.90)	3.93 (0.92)	4.33 (0.78)
Understand the controls	11	3.91 (1.14)	4.21 (0.80)	4.42 (0.67)
Make observations and collect data	11	3.73 (0.79)	4.07 (0.83)	4.42 (0.67)
Analyze numerical data	10	3.6 (1.07)	3.9 (1.10)	4.09 (0.83)
Interpret data	11	3.55 (1.04)	3.79 (1.05)	4.25 (0.75)
Reformulate the original hypothesis	10	3.5 (0.97)	3.85 (0.80)	4.3 (0.82)
Relate results to the bigger picture	11	3.73 (1.01)	4.36 (0.74)	4.67 (0.49)
Orally communicate the results	11	3.45 (0.93)	4 (0.88)	4.67 (0.65)
Write a scientific report	10	3.4 (0.97)	3.62 (0.87)	4.2 (0.79)
Think independently	11	3.36 (1.12)	4 (0.78)	4.42 (0.51)
Develop and use models	11	3.64 (1.03)	3.86 (0.95)	4.5 (0.67)
Mathematics-computational thinking	11	3.45 (1.21)	3.71 (1.27)	3.92 (1)
Constructing explanations	11	3.55 (0.93)	4 (0.78)	4.25 (0.62)
Engaging in argument from evidence	11	3.36 (1.03)	3.93 (0.92)	4.08 (0.67)

Table 11.
Mean and standard deviations in mid-initial, mid-now and post surveys of each group

Item	Group	N	Mid-Initial		Mid-now		Post	
			Mean	STD	Mean	STD	Mean	STD
Understand fundamental concepts	Research	7	3	1.15	3.86	0.69	4.43	0.79
	Well-drilling	2	3.5	0.71	4	0	3.5	0.71
	Lesson planning	2	4.5	0.71	5	0	5	0
Make use of primary literature	Research	7	3	1	4	0.58	4.43	0.53
	Well-drilling	2	3	0	4	0	4	0
	Lesson planning	2	5	0	5	0	5	0
Identify a specific question	Research	7	3.14	1.21	4.14	0.9	4.71	0.49
	Well-drilling	2	2.5	0.71	3	0	3	1.41
	Lesson planning	2	4.5	0.71	5	0	5	0
Formulate a research hypothesis	Research	7	3.29	1.38	3.86	0.9	4.57	0.53
	Well-drilling	2	2.5	0.71	3	0	3.5	0.71
	Lesson planning	2	4.5	0.71	5	0	5	0
Design an experiment	Research	7	3.14	0.69	3.86	0.9	4.43	0.79
	Well-drilling	2	2.5	0.71	3	0	3.5	0.71
	Lesson planning	2	4.5	0.71	5	0	4.5	0.71
Understand the controls	Research	7	4	1	4	0.82	4.57	0.53
	Well-drilling	2	2.5	0.71	3.5	0.71	3.5	0.71
	Lesson planning	2	5	0	5	0	4.5	0.71
Make observations and collect data	Research	7	3.71	0.76	4.14	0.69	4.71	0.49
	Well-drilling	2	3	0	3.5	0.71	3.5	0.71
	Lesson planning	2	4.5	0.71	5	0	4.5	0.71
Analyze numerical data	Research	6	3.67	1.03	3.83	1.17	4.17	0.98
	Well-drilling	2	2.5	0.71	3	0	3.5	0.71
	Lesson planning	2	4.5	0.71	5	0	4.5	0.71
Interpret data	Research	7	3.57	0.98	3.71	1.11	4.43	0.79
	Well-drilling	2	2.5	0.71	3	0	3.5	0.71
	Lesson planning	2	4.5	0.71	5	0	4.5	0.71
Reformulate the original hypothesis	Research	6	3.57	0.79	3.86	0.69	4.43	0.79
	Well-drilling	2	2.5	0.71	3	0	3.5	0.71
	Lesson planning	2	5		5		5	
Relate results to the bigger picture	Research	7	3.86	0.9	4.29	0.95	4.71	0.49
	Well-drilling	2	2.5	0.71	4	0	4	0
	Lesson planning	2	4.5	0.71	5	0	5	0
Orally communicate the results	Research	7	3.29	0.95	3.71	0.95	4.57	0.79
	Well-drilling	2	3	0	4	0	4.5	0.71
	Lesson planning	2	4.5	0.71	5	0	5	0
Write a scientific report	Research	6	3.33	0.82	3.5	0.84	4.33	0.82
	Well-drilling	2	2.5	0.71	3	0	3.5	0.71
	Lesson planning	2	4.5	0.71	5	0	4.5	0.71
Think independently	Research	7	3.29	1.11	3.86	0.69	4.43	0.53
	Well-drilling	2	2.5	0.71	3.5	0.71	4	0
	Lesson planning	2	4.5	0.71	5	0	4.5	0.71
Develop and use models	Research	7	3.71	0.95	3.86	0.9	4.57	0.53
	Well-drilling	2	2.5	0.71	3.5	0.71	3.5	0.71
	Lesson planning	2	4.5	0.71	5	0	5	0
Mathematics-computational thinking	Research	7	3.43	1.27	3.86	1.07	4.14	0.9
	Well-drilling	2	2.5	0.71	3	1.41	2.5	0.71
	Lesson planning	2	4.5	0.71	5	0	4.5	0.71
Constructing explanations	Research	7	3.43	0.98	3.86	0.69	4.43	0.53
	Well-drilling	2	3	0	3.5	0.71	3.5	0.71
	Lesson planning	2	4.5	0.71	5	0	4.5	0.71
Engaging in argument from evidence	Research	7	3.14	1.07	3.57	0.98	4	0.82
	Well-drilling	2	3	0	4	0	4	0
	Lesson planning	2	4.5	0.71	5	0	4.5	0.71

Table 12.
Results of repeated measures ANOVA for mid-initial, mid-now, post surveys

Item	Source	df	Sum of Squares	Mean Squares	*F*	p	η_p^2
Understand fundamental concepts	Time	2	2.092	1.046	3.08	0.0737	0.28
	Time*Group	4	2.026	0.506	1.49	0.2510	
	Error	16	5.429	0.339			
Make use of primary literature	Time	2	2.94	1.47	4.05	0.0378*	0.34
	Time*Group	4	1.766	0.442	1.22	0.3427	
	Error	16	5.81	0.363			
Identify a specific question	Time	2	3.19	1.595	3.01	0.0776	0.27
	Time*Group	4	1.463	0.366	0.69	0.6092	
	Error	16	8.476	0.53			
Formulate a research hypothesis	Time	2	3.414	1.707	3.33	0.0616	0.29
	Time*Group	4	0.597	0.149	0.29	0.8790	
	Error	16	8.19	0.512			
Design an experiment	Time	2	2.476	1.238	4.73	0.0244*	0.37
	Time*Group	4	1.506	0.377	1.44	0.2670	
	Error	16	4.19	0.262			
Understand the controls	Time	2	0.628	0.314	1.04	0.3746	0.12
	Time*Group	4	2.039	0.51	1.70	0.2001	
	Error	16	4.81	0.3			
Make observations and collect data	Time	2	1.254	0.626	2.24	0.1388	0.22
	Time*Group	4	1.221	0.305	1.09	0.3943	
	Error	16	4.476	0.28			
Analyze numerical data	Time	2	1.063	0.532	2.91	0.0875	0.29
	Time*Group	4	0.844	0.211	1.16	0.3712	
	Error	14	2.556	0.183			
Interpret data	Time	2	1.536	0.768	2.43	0.1194	0.23
	Time*Group	4	1.316	0.329	1.04	0.4159	
	Error	16	5.048	0.315			
Reformulate the original hypothesis	Time	2	1.058	0.529	2.02	0.1696	0.22
	Time*Group	4	0.4	0.1	0.38	0.8180	
	Error	14	3.667	0.262			
Relate results to the bigger picture	Time	2	4.155	2.077	5.45	0.0156*	0.41
	Time*Group	4	1.117	0.279	0.73	0.5827	
	Error	16	6.095	0.381			
Orally communicate the results	Time	2	4.771	2.385	11.45	0.0008*	0.59
	Time*Group	4	0.97	0.242	1.16	0.3634	
	Error	16	3.333	0.208			
Write a scientific report	Time	2	1.73	0.865	9.91	0.0021*	0.59
	Time*Group	4	1.511	0.378	4.33	0.0174	
	Error	14	1.222	0.087			
Think independently	Time	2	3.384	1.692	7.90	0.0041*	0.50
	Time*Group	4	1.602	0.4	1.87	0.1652	
	Error	16	3.429	0.214			
Develop and use models	Time	2	2.557	1.278	4.34	0.0312*	0.35
	Time*Group	4	0.922	0.23	0.78	0.5530	
	Error	16	4.714	0.295			
Mathematics-computational thinking	Time	2	0.893	0.447	2.03	0.1642	0.20
	Time*Group	4	0.961	0.24	1.09	0.3943	
	Error	16	3.524	0.22			
Constructing explanations	Time	2	1.253	0.626	2.63	0.1028	0.25
	Time*Group	4	1.221	0.305	1.28	0.3183	
	Error	16	3.81	0.238			
Engaging in argument from evidence	Time	2	2.092	1.046	3.78	0.0453*	0.32
	Time*Group	4	1.087	0.272	0.98	0.4453	
	Error	16	4.429	0.277			

Note. *The mean difference is significant at 0.05 level.

Table 13.
Tukey results for teachers mid-initial, mid-now and post surveys

Item	Survey (I)	Survey (J)	Mean Difference (I-J)	Minimum Difference for significance
Make use of primary literature	Post	Mid-initial	1.0909*	
		Mid-Now	0.2727	0.6629
	Mid-Now	Mid-initial	0.8182*	
Design an experiment	Post	Mid-initial	1*	
		Mid-Now	0.3636	0.5632
	Mid-Now	Mid-initial	0.6364*	
Relate results to the bigger picture	Post	Mid-initial	0.9091*	
		Mid-Now	0.2727	0.6791
	Mid-Now	Mid-initial	0.6364	
Orally communicate the results	Post	Mid-initial	1.1818*	
		Mid-Now	0.6364*	0.5018
	Mid-Now	Mid-initial	0.5455*	
Write a scientific report	Post	Mid-initial	0.8*	
		Mid-Now	0.5*	0.3245
	Mid-Now	Mid-initial	0.3	
Think independently	Post	Mid-initial	1*	
		Mid-Now	0.3636	0.5090
	Mid-Now	Mid-initial	0.6364*	
Develop and use models	Post	Mid-initial	0.8182*	
		Mid-Now	0.4545	0.5976
	Mid-Now	Mid-initial	0.3636	
Engaging in argument from evidence	Post	Mid-initial	0.7273*	
		Mid-Now	0.1818	
	Mid-Now	Mid-initial	0.5455	0.5791

Note. *The mean difference is significant at 0.05 level.

In addition to the ANOVA and Tukey analysis, a dependent means t-test was conducted to identify whether there is a statistically significant difference between the means of each items in pre- and mid-initial surveys (Table 14). The analysis results indicated there is a statistically significant difference only for the item to understand fundamental concepts between pre- and post-surveys Although most of the items have a higher mean in the pre-survey than in the mid-initial survey, none of them, except to understand fundamental concepts, showed a statistically significance difference ($p>0.05$).

In short, the analysis indicated that there is not a significant difference between the pre- and mid-initial surveys, except for understanding fundamental concepts practice. Both pre-, mid-now and post-survey analysis and mid-initial, mid-now and post-survey analysis results suggest that for teachers their abilities to make use of the primary scientific research literature, design an

Table 14.

Results of t-test for teacher pre and mid-initial surveys (N =14)

Item	Time			
	Pre	Mid-Initial	*t*	p
Understand fundamental concepts	3.87 (0.52)	3.07 (1.14)	2.62	0.0212*
Make use of primary literature	3.53 (0.64)	3 (1.24)	1.61	0.1309
Identify a specific question	3.4 (0.83)	2.93 (1.27)	1.38	0.1894
Formulate a research hypothesis	3.4 (0.91)	3.1 (1.23)	0.49	0.6349
Design an experiment	3.2 (0.68)	3 (0.96)	0.62	0.5470
Understand the controls	4 (1)	3.86 (1.17)	0.21	0.8364
Make observations and collect data	3.73 (0.88)	3.43 (0.94)	0.90	0.3854
Analyze numerical data	3.6 (1.06)	3.36 (1.08)	0.62	0.5470
Interpret data	3.47 (1.06)	3.29 (1.07)	0.37	0.7202
Reformulate the original hypothesis	3.33 (1.05)	3.36 (1.08)	-0.81	0.4346
Relate results to the bigger picture	3.53 (0.83)	3.36 (1.15)	0.43	0.6714
Orally communicate the results	3.4 (0.83)	3.07 (1.14)	1.15	0.2722
Write a scientific report	3.33 (0.82)	3 (1.11)	2.11	0.0548
Think independently	3.47 (0.83)	3 (1.24)	2.11	0.0548
Develop and use models	3.33 (0.82)	3.36 (1.08)	0.00	1.0000
Mathematics-computational thinking	3.27 (0.96)	3.14 (1.23)	0.00	1.0000
Constructing explanations	3.13 (0.92)	3.21 (1.12)	-0.32	0.7522
Engaging in argument from evidence	3.4 (0.99)	3.07 (1.07)	1.15	0.2722

Note. Standard deviations appear in parentheses below means. *The mean difference is significant at 0.05 level.

experiment, relate results to the bigger picture, orally communicate the results, write a scientific report, think independently, develop and use models, and engage in argument from evidence improved in the RET program.

Pre-, mid-now and post-survey analysis suggests that for teachers their abilities to understand fundamental concepts, identify a specific question, formulate a research hypothesis interpret data, reformulate the original hypothesis, mathematics-computational thinking, and constructing explanations improved from the beginning to the end of the program, mid-initial, mid-now and post-surveys did not indicate that improvement. Also, both analyses indicated that for teachers their abilities make use of primary literature, design an experiment, relate results to the bigger picture, orally communicate the results, write a scientific report, think independently, develop and use models, and engaging in argument from evidence improved from the beginning to the end of the program.

Graduate student survey results. Graduate students were administered a science practices survey at the end of the program to find out their perceptions of the RET teachers' abilities to engage in science practices. In that survey, they were asked to what extent the teachers they worked with were able to engage in each science practice at the beginning and at the end of the program. The survey was a 5-point Likert scale type and consisted of 18 items that are related to the science practices. The analysis indicated that for graduate students, mean values of teachers' abilities to engage in science practices in all items increased from the beginning to the end of the program (Table 15 and 16). In order to determine if there is a statistically significant difference between teachers' abilities to engage in science practices at the beginning and at the end of the RET program, repeated measures ANOVA was conducted for each item (Table 17). The analysis results indicated for the means of all items there is a statistically significant difference between initial and final surveys. This suggests the graduate students think that teachers' abilities to engage in science practices improved in the RET program. That means the graduate students think that the teachers in the well drilling and lesson planning groups also improved on the practices although they did not engage in research. One of the reasons for that result might be that they are graduate students in engineering, rather than graduate students in the sciences. That means their understandings of the practices might be different than the graduate students in the sciences, which might affect their evaluations of the teachers. Another reason which is more reasonable might be that the graduate students themselves are still apprentices, and they are not knowledge producers until they graduate. Therefore, their evaluations of the teachers might be suspect.

The graduate students think that at the end of the RET program the teachers were more able to design an experiment, understand the importance of controls, make observations and collect data, relate results to the bigger picture, orally communicate the results of the research, and think independently.

Table 15.
Mean and standard deviations in graduate student initial and final surveys (N=14)

	Initial		Final	
Item	Mean	STD	Mean	STD
Understand fundamental concepts	3.07	0.94	3.71	0.64
Make use of primary literature	2.71	0.51	3.21	0.7
Identify a specific question	2.79	0.58	3.61	0.68
Formulate a research hypothesis	2.79	0.73	3.54	0.75
Design an experiment	2.96	0.97	3.75	0.75
Understand the controls	3.36	0.63	3.96	0.5
Make observations and collect data	3	0.81	3.96	0.63
Analyze numerical data	2.71	1.01	3.29	0.75
Interpret data	3	0.9	3.5	0.55
Reformulate the original hypothesis	2.71	0.85	3.39	0.74
Relate results to the bigger picture	3.21	0.97	4.14	0.93
Orally communicate the results	3	1.13	4.21	0.89
Write a scientific report	2.79	0.89	3.39	0.84
Think independently	3.11	1	3.79	0.7
Develop and use models	2.29	0.93	2.89	1.04
Mathematics-computational thinking	2.39	1.08	2.82	0.99
Constructing explanations	2.89	0.96	3.86	0.86
Engaging in argument from evidence	2.79	0.91	4.07	1

Table 16.
Mean and standard deviations in graduate student initial and final surveys of each group

Item	Group	N	Initial		Final	
			Mean	STD	Mean	STD
Understand fundamental concepts	Research	6	2.83	1.21	3.67	0.88
	Well-drilling	3	3.67	0.58	4	0
	Lesson planning	5	3	0.71	3.6	0.55
Make use of primary literature	Research	6	2.5	0.63	2.83	0.41
	Well-drilling	3	3	0	3.33	0.58
	Lesson planning	5	2.8	0.45	3.6	0.89
Identify a specific question	Research	6	2.67	0.82	3.42	0.66
	Well-drilling	3	3	0	3.67	0.58
	Lesson planning	5	2.8	0.45	3.8	0.84
Formulate a research hypothesis	Research	6	2.5	0.89	3.25	0.76
	Well-drilling	3	3	0	3.67	0.58
	Lesson planning	5	3	0.71	3.8	0.84
Design an experiment	Research	6	2.75	1.17	3.58	0.92
	Well-drilling	3	3.67	1.15	4.33	0.58
	Lesson planning	5	2.8	0.45	3.6	0.55
Understand the controls	Research	6	3	0.63	3.75	0.61
	Well-drilling	3	3.67	0.58	4.33	0.58
	Lesson planning	5	3.6	0.55	4	0
Make observations and collect data	Research	6	2.5	0.63	3.75	0.61
	Well-drilling	3	3.67	0.58	4.33	0.58
	Lesson planning	5	3.2	0.84	4	0.71
Analyze numerical data	Research	6	2.17	0.52	3	0.71
	Well-drilling	3	4	0	4	0
	Lesson planning	5	2.6	1.14	3.2	0.84
Interpret data	Research	6	2.5	0.89	3.33	0.61
	Well-drilling	3	4	0	4	0
	Lesson planning	5	3	0.71	3.4	0.55
Reformulate the original hypothesis	Research	6	2.17	0.52	2.92	0.8
	Well-drilling	3	3.67	0.58	4	0
	Lesson planning	5	2.8	0.84	3.6	0.55
Relate results to the bigger picture	Research	6	2.5	0.84	3.5	1
	Well-drilling	3	4	0	4.67	0.58
	Lesson planning	5	3.6	0.89	4.6	0.55
Orally communicate the results	Research	6	2.17	0.52	3.67	1.03
	Well-drilling	3	3.67	0.58	4.33	0.58
	Lesson planning	5	3.6	1.34	4.8	0.45
Write a scientific report	Research	6	2.33	0.52	2.92	0.8
	Well-drilling	3	3.33	0.58	3.33	0.58
	Lesson planning	5	3.00	1.22	4	0.71
Think independently	Research	6	2.42	0.66	3.33	0.82
	Well-drilling	3	3.67	1.15	4	0
	Lesson planning	5	3.6	0.89	4.2	0.45
Develop and use models	Research	6	1.83	0.52	2.25	0.88
	Well-drilling	3	3.67	1.15	4	1
	Lesson planning	5	2	0	3	0.71
Mathematics-computational thinking	Research	6	1.58	0.66	2.25	0.88
	Well-drilling	3	3.33	0.58	3.67	1.15
	Lesson planning	5	2.8	1.10	3	0.71
Constructing explanations	Research	6	2.25	0.61	3.33	1.03
	Well-drilling	3	3.33	0.578	4	0
	Lesson planning	5	3.4	1.14	4.4	0.55
Engaging in argument from evidence	Research	6	2.17	0.52	3.33	1.03
	Well-drilling	3	3.67	0.58	4.33	0.58
	Lesson planning	5	3	1	4.8	0.45

Table 17.
Results of repeated measures ANOVA for graduate student initial and final surveys

Item	Source	df	Sum of Squares	Mean Squares	*F*	p	η_p^2
Understand fundamental concepts	Time	1	2.229	2.229	18.17	0.0013*	0.62
	Time*Group	2	0.257	0.129	1.05	0.3833	
	Error	11	1.35	0.123			
Make use of primary literature	Time	1	1.537	1.537	5.37	0.0408*	0.33
	Time*Group	2	0.35	0.175	0.61	0.5602	
	Error	11	3.15	0.286			
Identify a specific question	Time	1	4.172	4.172	12.17	0.0051*	0.53
	Time*Group	2	0.131	0.065	0.19	0.8288	
	Error	11	3.771	0.343			
Formulate a research hypothesis	Time	1	3.51	3.51	17.78	0.0014*	0.62
	Time*Group	2	0.017	0.008	0.04	0.9588	
	Error	11	2.171	0.197			
Design an experiment	Time	1	3.779	3.779	29.69	0.0002*	0.73
	Time*Group	2	0.029	0.014	0.11	0.8948	
	Error	11	1.4	0.127			
Understand the controls	Time	1	2.357	2.357	18.92	0.0012*	0.63
	Time*Group	2	0.174	0.087	0.70	0.5186	
	Error	11	1.371	0.125			
Make observations and collect data	Time	1	5.272	5.272	18.29	0.0013*	0.62
	Time*Group	2	0.445	0.223	0.77	0.4855	
	Error	11	3.171	0.288			
Analyze numerical data	Time	1	1.467	1.467	8.00	0.0164*	0.42
	Time*Group	2	0.698	0.349	1.90	0.1952	
	Error	11	2.017	0.183			
Interpret data	Time	1	1.087	1.087	5.93	0.0331*	0.35
	Time*Group	2	0.733	0.367	2.00	0.1816	
	Error	11	2.017	0.183			
Reformulate the original hypothesis	Time	1	2.534	2.534	12.84	0.0043*	0.54
	Time*Group	2	0.231	0.115	0.59	0.5735	
	Error	11	2.171	0.197			
Relate results to the bigger picture	Time	1	5.079	5.079	21.63	0.0007*	0.66
	Time*Group	2	0.131	0.065	0.28	0.7619	
	Error	11	2.583	0.235			
Orally communicate the results	Time	1	8.096	8.096	18.81	0.0012*	0.63
	Time*Group	2	0.695	0.348	0.81	0.4706	
	Error	11	4.733	0.430			
Write a scientific report	Time	1	1.791	1.791	7.56	0.0189*	0.41
	Time*Group	2	0.940	0.470	1.99	0.1835	
	Error	11	2.604	0.237			
Think independently	Time	1	2.445	2.445	13.20	0.0039*	0.55
	Time*Group	2	0.364	0.182	0.98	0.4047	
	Error	11	2.038	0.185			
Develop and use models	Time	1	2.188	2.188	12.42	0.0048*	0.53
	Time*Group	2	0.607	0.304	1.72	0.2233	
	Error	11	1.938	0.176			
Mathematics-computational thinking	Time	1	1.029	1.029	8.08	0.0160	
	Time*Group	2	0.314	0.157	1.23	0.3283	
	Error	11	1.400	0.127			
Constructing explanations	Time	1	5.402	5.402	30.67	0.0002*	0.74
	Time*Group	2	0.179	0.089	0.51	0.6158	
	Error	11	1.938	0.176			
Engaging in argument from evidence	Time	1	9.429	9.429	23.57	0.0005*	0.68
	Time*Group	2	1.279	0.639	1.60	0.2459	
	Error	11	4.4	0.4			

Note. *The mean difference is significant at 0.05 level.

They also think the teachers were least able to analyze numerical data, use mathematics and computational thinking, develop and use models, make use of the primary scientific research literature, reformulate the original hypothesis, and write a scientific report of research. They think that while the least improvement was seen in teachers' abilities to make use of the primary scientific research literature, the biggest improvements were seen in their ability to design an experiment. Partial eta squared (η_p^2) was used to report the effect size. A very large effect was found for all items because η_p^2 greater than 0.14 (Cohen, 1988).

The teacher and graduate student survey analysis indicated that both teachers and graduate students think that teachers' abilities to make use of primary literature, design an experiment, relate results to the bigger picture, orally communicate the results of research, write a scientific report, think independently about research area, develop and use models, and engaging in argument from evidence improved in the RET program. The results also suggest that although for graduate students there is an improvement on teachers' abilities to make observations and collect data and analyze numerical data, the teachers' pre-, mid-initial, and post-survey analysis did not indicate an improvement on those practices. In addition, although the graduate students think that the teachers' abilities to understand fundamental concepts identify a specific question, formulate a research hypothesis analyze numerical data, interpret data, reformulate the original hypothesis, constructing explanations improved, the teachers' mid-initial, mid-now and post-survey analysis did not indicate an improvement.

The Results for the Research Apprenticeship Group

As it is seen in table 14, the teachers' ratings in the pre-survey are higher than the mid-initial survey. When they were asked why their ratings were higher in the pre-survey but lower in the mid-initial survey, although both questions measure their abilities at the beginning of the program, they said they thought that they knew how to do research and engage in those practices, but once they began and gained more experience in research they realized that they did not know much about it. Therefore, their ratings were lower in the mid-initial survey. A similar situation is identified when the ratings of the research, well-drilling, and lesson planning apprenticeship groups were compared. The ratings and mean values of the teachers in the well-drilling and lesson planning groups are higher than the teachers in the research apprenticeship group. This finding suggests that the teachers in the well-drilling and lesson planning group did not have a research experience in the RET program; therefore, they did not have much knowledge about what it means to engage in those practices, and they did not have an opportunity to realize their levels of engaging in those practices. Therefore, their ratings about themselves do not change the way of the teachers in the research group did. Since the previous AVOVA and Tukey analysis provide the results for the three groups, in this section the analysis of the teachers only in the research group are also presented separately in order to see in which practices they improved after they had a research experience.

Research apprenticeship group pre-, mid-, and post-survey results. The analysis indicated that the means of all items increased from pre- to mid-now and to the post-surveys (Table 7). The repeated measures ANOVA analysis indicated that there is a statistically significant difference for the means of the eight science practices (Table 18). These items are design an experiment, make observations and collect data, orally communicate the results of research, reformulate the original hypothesis, write a scientific report, think independently about research area, develop and use models, and constructing explanations. Partial eta squared (η_p^2) was used to report the effect size. Very large effect is found for all items because η_p^2 greater than 0.14 (Cohen, 1988).

Table 18.
Results of repeated measures ANOVA for research apprenticeship group pre, mid-now and post surveys

Item	Source	df	Sum of Squares	Mean Squares	*F*	p	η_p^2
Understand fundamental concepts	Time	2	1.143	0.571	2.40	0.1328	0.29
	Error	12	2.857	0.238			
Make use of primary literature	Time	2	1.238	0.619	2.69	0.1084	0.30
	Error	12	2.762	0.230			
Identify a specific question	Time	2	3.524	1.762	3.64	0.0582	0.38
	Error	12	5.81	0.484			
Formulate a research hypothesis	Time	2	2.952	1.476	3.51	0.0631	0.37
	Error	12	5.048	0.421			
Design an experiment	Time	2	4.571	2.286	6.70	0.0111*	0.53
	Error	12	4.095	0.341			
Understand the controls	Time	2	2	1	1.8	0.2072	0.23
	Error	12	6.667	0.556			
Make observations and collect data	Time	2	2.667	1.333	4.80	0.0294*	0.44
	Error	12	3.333	0.2778			
Analyze numerical data	Time	2	1.333	0.667	1.67	0.2373	0.25
	Error	10	4	0.4			
Interpret data	Time	2	2.381	1.190	2.88	0.0949	0.32
	Error	12	4.952	0.413			
Reformulate the original hypothesis	Time	2	2.667	1.333	4	0.0467*	0.40
	Error	12	4	0.333			
Relate results to the bigger picture	Time	2	4.667	2.333	3.82	0.0521	0.39
	Error	12	7.3333	0.611			
Orally communicate the results	Time	2	4.952	2.476	6.78	0.0107*	0.53
	Error	12	4.381	0.365			
Write a scientific report	Time	2	2.333	1.167	7.00	0.0126*	0.58
	Error	10	1.667	0.167			
Think independently	Time	2	2.667	1.333	12.00	0.0014*	0.67
	Error	12	1.333	0.111			
Develop and use models	Time	2	2.952	1.476	5.81	0.0172*	0.49
	Error	12	3.048	0.254			
Mathematics-computational thinking	Time	2	1.143	0.571	3.13	0.0805	0.34
	Error	12	2.190	0.183			
Constructing explanations	Time	2	3.524	1.762	11.68	0.0015*	0.66
	Error	12	1.81	0.151			
Engaging in argument from evidence	Time	2	1.238	0.619	2.17	0.1573	0.27
	Error	12	3.429	0.286			

Note. *The mean difference is significant at 0.05 level.

For the items that were statistically different in ANOVA, a Tukey test was used to make all pairwise comparisons between pre-, mid-now and post-surveys in order to see which pair or pairs have the significant difference for the means of those items. The Tukey results are presented in Table 19. The statistically significant differences were found between pre- and post-surveys for the means of the items design an experiment, make observations and collect data, orally communicate the results of research, reformulate the original hypothesis, and develop and use models practices. In addition, the means of the items write a scientific report of research, think independently, and construct explanations practices indicated statistical significant difference between (a) pre- and post-, and (b) mid-now and post-surveys.

Table 19.

Tukey results for research apprenticeship group pre, mid-now and post surveys

Item	Survey (I)	Survey (J)	Mean Difference (I-J)	Minimum Difference for Significance
Design an experiment	Post	Pre	1.14*	
		Mid-Now	0.57	
	Mid-Now	Pre	0.57	0.83
Make observations and collect data	Post	Pre	0.85*	
		Mid-Now	0.57	
	Mid-Now	Pre	0.28	0.75
Reformulate the original hypothesis	Post	Pre	0.86*	
		Mid-Now	0.57	
	Mid-Now	Pre	0.29	0.82
Orally communicate the results	Post	Pre	1.14*	
		Mid-Now	0.86	
	Mid-Now	Pre	0.28	0.86
Write a scientific report	Post	Pre	0.66*	
		Mid-Now	0.83*	
	Mid-Now	Pre	0.17	0.58
Think independently	Post	Pre	0.86*	
		Mid-Now	0.57*	
	Mid-Now	Pre	0.29	0.48
Develop and use models	Post	Pre	0.86*	
		Mid-Now	0.71	
	Mid-Now	Pre	0.15	0.72
Constructing explanations	Post	Pre	1*	
		Mid-Now	0.57*	
	Mid-Now	Pre	0.43	0.55

Note. *The mean difference is significant at 0.05 level.

In addition, for the research apprenticeship group their mid-initial, mid-now and post-surveys were also analyzed. The analysis indicated that in general the mean values of each item increased from mid-initial to mid-now and to post-surveys (Table 11). The ANOVA analysis indicated that the means of the items understand the importance of controls, analyze numerical data, relate results to the bigger picture, use mathematics and computational thinking and engage in arguments from evidence practices did not indicate a statistically significant difference between mid-initial, mid-now and post-surveys ($p>0.05$) (Table 20). There is a statistically significant difference for all the other items between mid-initial, mid-now and post surveys ($p<0.05$). Partial eta squared (η_p^2) was used to report the effect size. Very large effect is found for all items because η_p^2 greater than 0.14 (Cohen, 1988).

Table 20.
Results of repeated measures ANOVA for research apprenticeship group mid-initial, mid-now and post surveys

Item	Source	df	Sum of Squares	Mean Squares	*F*	p	η_p^2
Understand fundamental concepts	Time	2	7.238	3.619	9.12	0.0039*	0.60
	Error	12	4.762	0.397			
Make use of primary literature	Time	2	7.524	3.762	7.77	0.0068*	0.56
	Error	12	5.81	0.484			
Identify a specific question	Time	2	8.857	4.429	7.44	0.0079*	0.55
	Error	12	7.143	0.595			
Formulate a research hypothesis	Time	2	5.81	2.905	4.63	0.0323*	0.44
	Error	12	7.524	0.627			
Design an experiment	Time	2	5.81	2.905	9.89	0.0029*	0.62
	Error	12	3.524	0.294			
Understand the controls	Time	2	1.524	0.762	2.04	0.1724	0.25
	Error	12	4.476	0.373			
Make observations and collect data	Time	2	3.524	1.762	6.73	0.0110*	0.53
	Error	12	3.143	0.262			
Analyze numerical data	Time	2	0.778	0.389	2.06	0.1783	0.29
	Error	10	1.889	0.189			
Interpret data	Time	2	2.952	1.476	4.04	0.0455*	0.40
	Error	12	4.381	0.365			
Reformulate the original hypothesis	Time	2	2.667	1.333	4.80	0.0294*	0.44
	Error	12	3.333	0.278			
Relate results to the bigger picture	Time	2	2.571	1.286	2.84	0.0976	0.32
	Error	12	5.429	0.452			
Orally communicate the results	Time	2	6.000	3.00	13.50	0.0008*	0.69
	Error	12	2.667	0.222			
Write a scientific report	Time	2	3.444	1.722	31.00	<.0001*	0.86
	Error	10	0.556	0.056			
Think independently	Time	2	4.571	2.286	9.93	0.0029*	0.62
	Error	12	2.762	0.230			
Develop and use models	Time	2	2.952	1.476	5.81	0.0172*	0.49
	Error	12	3.048	0.254			
Mathematics-computational thinking	Time	2	1.81	0.905	3.80	0.0527	0.39
	Error	12	2.857	0.238			
Constructing explanations	Time	2	3.524	1.762	8.54	0.0049*	0.59
	Error	12	2.476	0.206			
Engaging in argument from evidence	Time	2	2.571	1.286	3.77	0.0537	0.39
	Error	12	4.095	0.341			

Note. *The mean difference is significant at 0.05 level.

For the items that were statistically different in ANOVA, a Tukey test was used to make all pairwise comparisons between mid-initial, mid-now and post-surveys in order to see which pair or pairs have the significant difference for the means of those items (Table 21). Statistically significant differences were between (a) mid-initial and post-, and (b) mid-now and post-surveys for the means of the items orally communicate the results of research and write a scientific research report.

Table 21.

Tukey results for research apprenticeship group mid-initial, mid-now and post surveys

Item	Survey (I)	Survey (J)	Mean Difference (I-J)	Minimum Difference for Significance
Understand fundamental concepts	Post	Mid-initial	0.29	0.8983
		Mid-Now	0.57	
	Mid-Now	Mid-initial	-0.28	
Make use of primary literature	Post	Mid-initial	0.57	0.9922
		Mid-Now	0.43	
	Mid-Now	Mid-initial	0.14	
Identify a specific question	Post	Mid-initial	1	1.1002
		Mid-Now	0.57	
	Mid-Now	Mid-initial	0.43	
Formulate a research hypothesis	Post	Mid-initial	0.86	1.1292
		Mid-Now	0.71	
	Mid-Now	Mid-initial	0.15	
Design an experiment	Post	Mid-initial	1.14*	0.7728
		Mid-Now	0.57	
	Mid-Now	Mid-initial	0.57	
Make observations and collect data	Post	Mid-initial	0.85*	0.7298
		Mid-Now	0.57	
	Mid-Now	Mid-initial	0.28	
Interpret data	Post	Mid-initial	0.72	0.8617
		Mid-Now	0.72	
	Mid-Now	Mid-initial	0	
Reformulate the original hypothesis	Post	Mid-initial	0.86*	0.7516
		Mid-Now	0.57	
	Mid-Now	Mid-initial	0.29	
Orally communicate the results	Post	Mid-initial	1.14*	0.6722
		Mid-Now	0.86*	
	Mid-Now	Mid-initial	0.28	
Write a scientific report	Post	Mid-initial	0.66*	0.3361
		Mid-Now	0.83*	
	Mid-Now	Mid-initial	-0.17	
Think independently	Post	Mid-initial	0.86*	0.6842
		Mid-Now	0.57	
	Mid-Now	Mid-initial	0.29	
Develop and use models	Post	Mid-initial	0.86*	0.7187
		Mid-Now	0.71	
	Mid-Now	Mid-initial	0.15	
Constructing explanations	Post	Mid-initial	1*	0.6478
		Mid-Now	0.57	
	Mid-Now	Mid-initial	0.43	

Note. *The mean difference is significant at 0.05 level

In addition, there were statistically significant differences between the means of mid-initial and post-surveys for the items design an experiment, make observations and collect data, reformulate the original hypothesis, think independently, develop and using models and construct explanations. Although the ANOVA analysis is significant for the items understand the fundamental concepts of research, make use of the primary scientific research literature, identify a specific question for investigation, formulate a research hypothesis, and interpret data, the Tukey test indicated there are no pairwise differences between means that are statistically different from each other.

Graduate student t-test analysis. The t-test analysis of initial and final surveys indicated that except for make use of the primary scientific research literature and develop and use models practices there is a statistically significant difference for all the other science practices ($p<0.05$) (Table 22). This suggests that for graduate students in the research apprenticeship group the teachers' abilities to engage in most of the science practices improved from the beginning to the end of the program. The graduate students think that at the end of the program the teachers were more able to design an experiment, understand the importance of controls, make observations and collect data, orally communicate the results of the research, and relate results to the bigger picture. They also think that at the end of the program the teachers were least able to use and analyze numerical data, make use of the primary scientific research literature, reformulate the original hypothesis, develop and use models, and write a scientific report of research. They think that while the least improvement was seen in teachers' abilities to write a scientific research report, the biggest improvements were seen in think independently and relate results to the bigger picture practices. Also, large effect is found for all items because Cohen's d is greater than 0.8 (Cohen, 1988).

Overall, the teacher and graduate student survey analysis indicated that both teachers and graduate students think that teachers' abilities to design an experiment, make observations and collect data, interpret data, reformulate the original hypothesis, orally communicate the results of research, write a scientific report, think independently about research area, develop and use models, and constructing explanations improved in the RET program.

Table 22.
Results of t-test for graduate student initial and final surveys for research apprenticeship group (N =6)

Item	Time				
	Initial	Final	*t*	p	*d*
Understand fundamental concepts	2.83 (1.21)	3.67 (0.88)	5.00	0.0041*	2.04
Make use of primary literature	2.5 (0.63)	2.83 (0.41)	2.00	0.1019	0.82
Identify a specific question	2.67 (0.82)	3.42 (0.66)	4.39	0.0071*	1.79
Formulate a research hypothesis	2.5 (0.89)	3.25 (0.76)	4.39	0.0071*	1.79
Design an experiment	2.75 (1.17)	3.58 (0.92)	3.95	0.0108*	1.61
Understand the controls	3 (0.63)	3.75 (0.61)	4.39	0.0071*	1.79
Make observations and collect data	2.5 (0.63)	3.75 (0.61)	4.04	0.0099*	1.65
Analyze numerical data	2.17 (0.52)	3 (0.71)	5.00	0.0041*	2.04
Interpret data	2.5 (0.89)	3.33 (0.61)	5.00	0.0041*	2.04
Reformulate the original hypothesis	2.17 (0.52)	2.92 (0.8)	4.39	0.0071*	1.79
Relate results to the bigger picture	2.5 (0.84)	3.5 (1)	7.75	0.0006*	3.16
Orally communicate the results	2.17 (0.52)	3.67 (1.03)	5.81	0.0021*	2.37
Write a scientific report	2.33 (0.52)	2.92 (0.8)	2.91	0.0335*	1.19
Think independently	2.42 (0.66)	3.33 (0.82)	11.00	0.0001*	4.49
Develop and use models	1.83 (0.52)	2.25 (0.88)	2.08	0.0925	0.85
Mathematics-computational thinking	2.25 (0.61)	3.33 (1.03)	3.16	0.0250*	1.29
Constructing explanations	1.58 (0.66)	2.25 (0.88)	5.40	0.0029*	2.2
Engaging in argument from evidence	2.17 (0.52)	3.33 (1.03)	5.53	0.0026*	2.26

Note. Standard deviations appear in parentheses below means.
*The mean difference is significant at 0.05 level.

The results also suggest that although for graduate students there is an improvement in teachers' abilities to understand fundamental concepts, identify a specific question, formulate a research hypothesis, understand the controls, analyze numerical data, interpret data, relate results to the bigger picture, and mathematics-computational thinking, the teachers' pre-, mid-initial and post-survey analysis did not indicate an improvement on those practices. In addition, although the graduate students think that the teachers' abilities to understand the controls, analyze numerical data, relate results to the bigger picture, mathematics-computational thinking improved, the teachers' mid-initial, mid-now and post-survey analysis did not indicate an improvement.

Ivette's Abilities to Engage in Science Practices

Ivette completed the pre-, mid-, and post-science practices surveys and was asked to what extent she was able to participate in the science practices. The results of those surveys for Ivette are presented in Figures 4, 5 and 6. In addition to that, after the RET program ended, the graduate student mentor and her professor were asked to rate her abilities of engaging in science practices in the beginning and at the end of the program (Figure 7 and 8). Ivette's self-reported ratings indicated that she thinks her science practices levels increased from the beginning to the end of the program. In general, her ratings in the post survey for each science practice, except primary literature and formulate a hypothesis (pre- and post- ratings were the same), analyze and interpret data (mid-initial and post-ratings were the same), are higher than the ratings in the pre- and mid-initial surveys.

Her ratings for understand fundamental concepts, make use of primary scientific research literature, identify a specific question for investigation, formulate a research hypothesis, make observations and collect data practices are lower in the mid-initial than in the pre-survey (Figure

4 and 6). This indicates she tended to overrate her science practices at the beginning but then changed her mind and lowered her ratings for her abilities at the beginning of the RET program. The range in the pre- and mid-initial survey is 3-4 (Figure 4 and 6) and the range in the graduate student initial rating is 3-4 and professor initial rating is 1-2 (Figure 7 and 8).

Graduate student and professor surveys also indicated that all Ivette's science practices levels increased from the beginning to the end of the program (Figure 7 and 8). The range in the final survey for the graduate student rating is 4-5 and for the professor rating the range is 2-4. Ivette's post-survey ratings and the graduate student-professor ratings in the final survey indicated that make observations and collect data and relate results to the bigger picture are the highest rated practices for Ivette. The graduate student emphasized her improvement in ability to make observations and collect data as below in the post interview, "Make observations and collect data, this one definitely she learned a lot in the first couple of weeks, later she was able to do her own tests and collect her data" (Graduate student interview, 9/4/2013). When I observed Ivette in the lab, she was running tests such as conductivity, pH, COD, and turbidity for different water samples that were taken from the reactors. She was able to run the tests and record her observations very carefully. In the interview, for relating results to the bigger picture practice the graduate student explained the following:

> Relate research results to the bigger picture; yes so, because of the part that she was doing she understood why it was important to the experiment. She understood that if that change in any way it would affect the whole aquaculture system that we have in the lab. So, I think she can understand that you know every little experiment was part of this huge puzzle that is the research we are working on. (Graduate student interview, 9/4/2013).

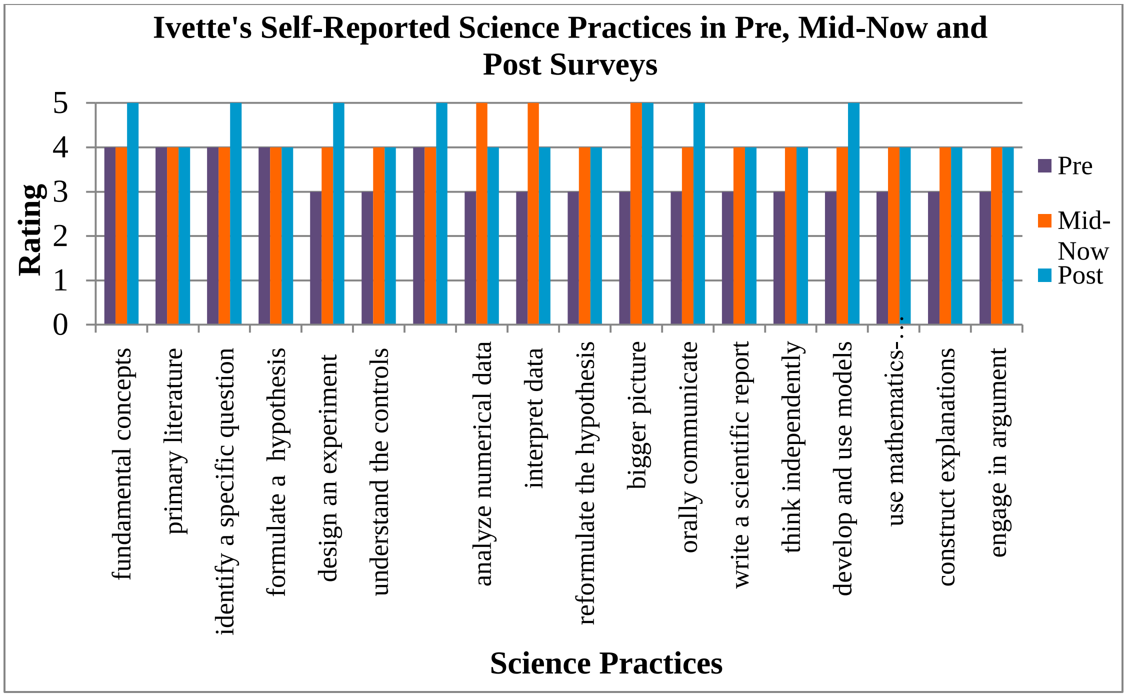

Figure 4. Ivette's self-reported pre, mid-now, and post survey ratings

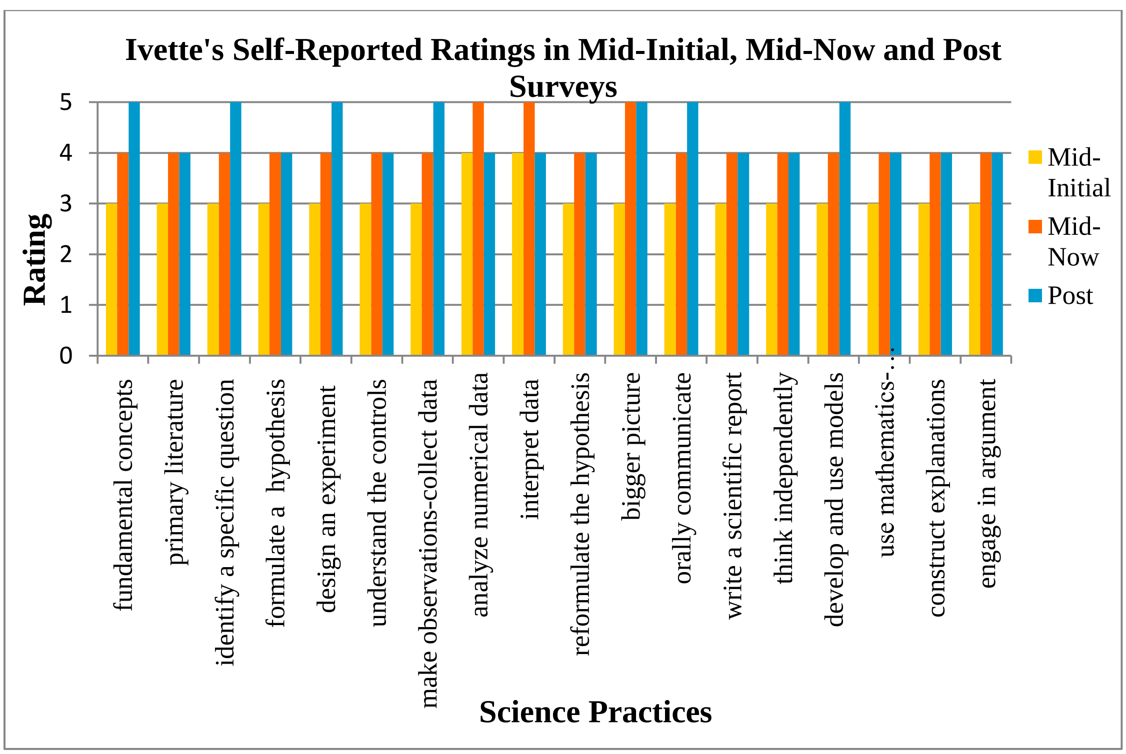

Figure 5. Ivette's self-reported mid-initial, mid-now, and post survey ratings

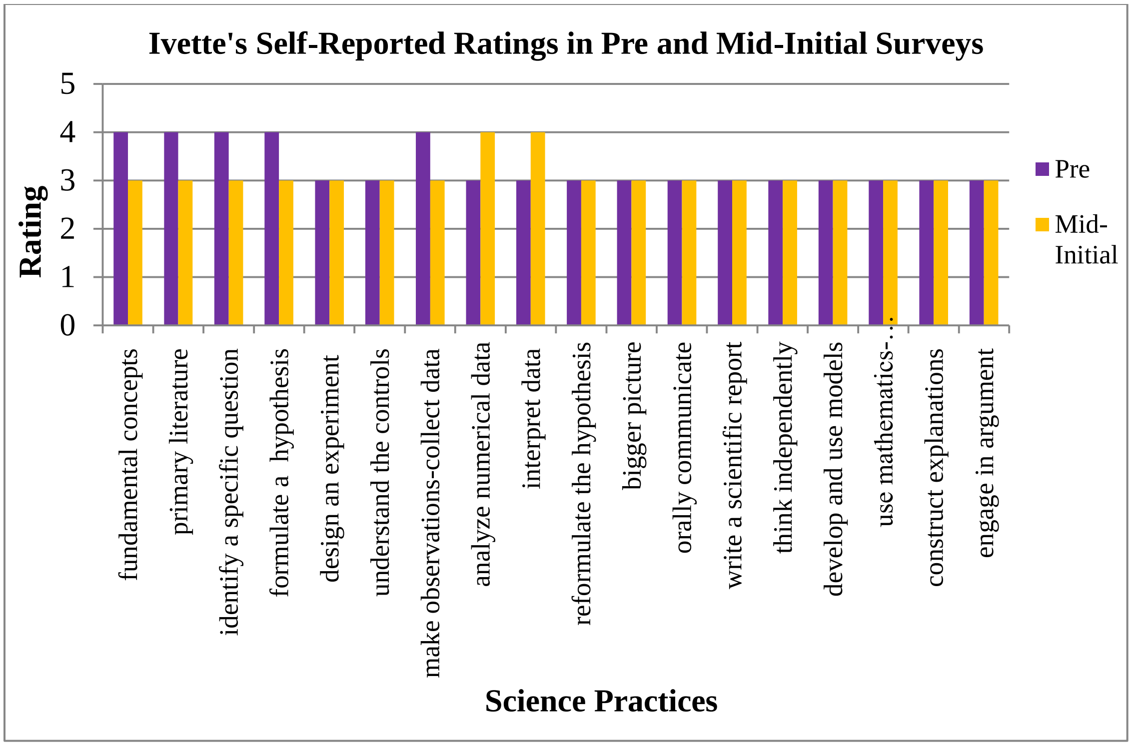

Figure 6. Ivette's self-reported pre and mid-initial survey ratings

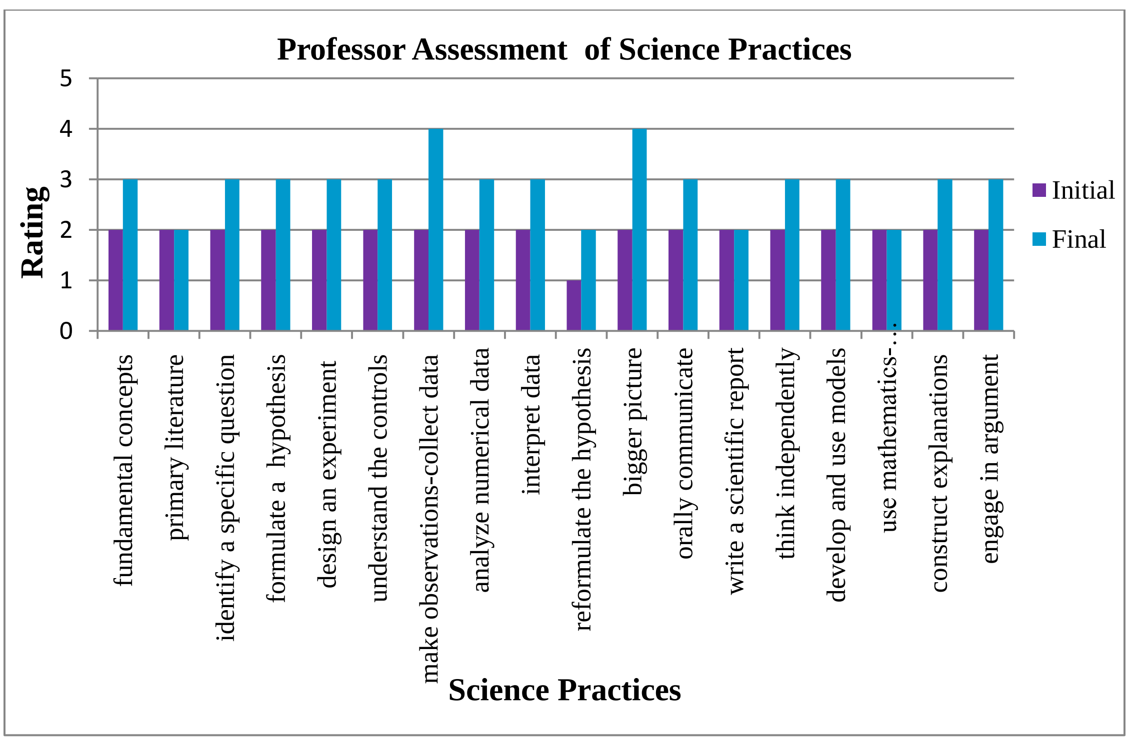

Figure 7. Professor assessment of science practices for Ivette

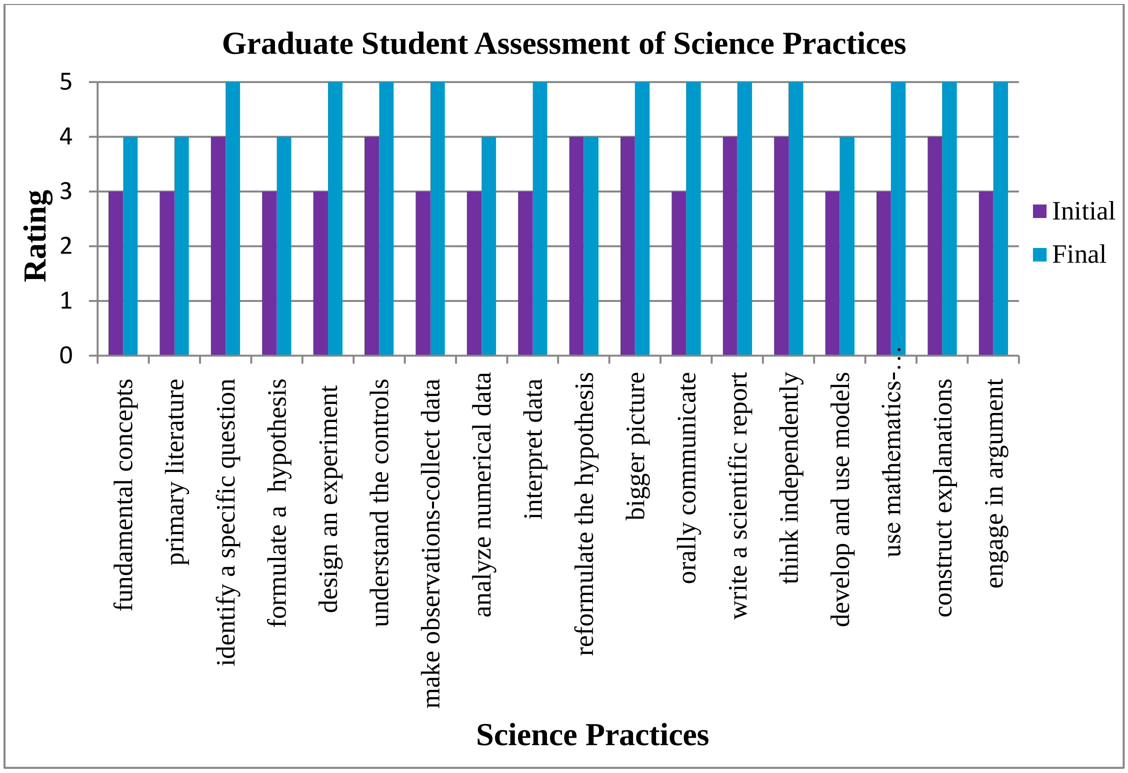

Figure 8. Graduate student's assessment of science practices for Ivette

The survey results indicated that for Ivette her ability to understand fundamental concepts, identify a specific question for investigation, design an experiment, make observations and collect data, orally communicate the results of research, develop and use models increased from mid-initial to mid-now and to the post-surveys. Similarly, her graduate student and professor ratings indicated she improved on those practices from the beginning to the end of the program. For instance, in the interview her graduate student stated that as follows:

> Identify a specific question for investigation, well I think she learned and she improved on that based on the fact that initially we were not really sure what we wanted her to do, she was learning, we kept discussing possibility for experiments and she really had an input on what we are trying to do. And I think she is capable of developing questions or

even identifying, you know what we are doing, what is a question that we are trying to answer. (Graduate student interview, 9/4/2013).

Ivette's oral communication ability improved in the program as well. The comparisons of my observations in the lab in the middle of the program and in the poster presentation, there was a difference in terms of the way that she explained her research and its components such as the research question, how she collected the data, analyzed the data, what is her interpretation, and making connections to the bigger picture.

Although Ivette's self-reported ratings were the same for her ability to formulate a research hypothesis, understand the importance of controls, construct explanations and engage in argument from evidence practices in the mid-now and post-surveys (her rating was 4=quite a bit), the graduate student and professor rating indicates improvement for those practices. While Ivette and the professor think that her ability to make use of the primary scientific research literature, write a scientific research report and use mathematics and computational thinking did not improve in the program, the graduate student thought those practices increased. In addition, while Ivette and the graduate student thought her ability to reformulate the original hypothesis did not improve, the professor thought there was an increase in her ability. The ratings indicated that the amount of increase is very low for make use of the primary scientific research literature, formulate a hypothesis, and write a scientific report practices. The graduate student and professor survey indicated that make use of the primary scientific research literature and reformulate the original hypothesis are the lowest science practices for Ivette (mean rating is 3 = somewhat). The graduate student stated that, "We did not get to reformulate the original hypothesis because we saw what we expected but I think she is able to do that as well."

Interestingly, her ratings for analyze numerical data and interpret data by relating results to the original hypothesis practices were the highest ones in the mid-now survey (rating is 5) but then she lowered her ratings to 4 in the post survey. In post interview, Ivette expressed her thoughts about data analysis as follows:

> Oh my God, what it means to me the most hard ever, it is really hard, I am still learning on that. This is one of the areas I consider that I need to keep working on and make some improvement but it is very important in the research and it is a lot of work because that is basically what is used for your conclusions. That is like the heaviest part of the research okay here is my results, this is what I obtained, and this is what it means and all that. So, I am still working on that. (Post interview, 8/16/2013).

The graduate student and professor ratings of analyze numerical data and interpret data increased from the beginning to the end of the program. In the post survey, graduate student's ratings are 4 and 5 and professor's ratings are 3 and 3, respectively.

The survey results indicate that Ivette thinks her ability to write a scientific report of research practice improved from the beginning to middle of the program but her ratings in the mid-now and post-surveys are same. The graduate student survey also indicated that there is a very little improvement in that practice. In the interview, the graduate student said she did not write a full report, except for the poster. She stated that as below:

> Researcher: Did she write a scientific report?
>
> Graduate Student: We are writing one, but it is due in December and it is not as developed as we want to be but a lot of the data experiment she did is going towards that and probably the paper will be published.

In addition, Ivette's explanation was similar to that in the post interview:

Researcher: Did you write a scientific report in the summer program?

Ivette: No not really. Unless you say this poster is a scientific report. Scientific reports? No, I did not write it down; I just worked on the poster. It was like kind of a more simple way of it but not like a report itself not really. I don't think we have to.

Overall, the results indicated that for Ivette, her graduate student mentor and the professor think that Ivette's abilities in the science practices were low at the beginning of the RET program. Most of their ratings were between 2 and 3. At the end of the program, she improved on the science practices. The practices that have the most improvements are identify a specific question for investigation, formulate a research hypothesis, design an experiment, collect data, interpret data, relate results to the bigger picture, orally communicate the results of research, understand fundamental concepts, and engaging in argument from evidence. The practices that she had the least improvement are make use of the primary scientific research literature, reformulate the original hypothesis, and write a scientific report of research. The results also suggest that she is more able to identify a question for investigation, design an experiment, understand the importance of controls, make observations and collect data, interpret data, relate results to the bigger picture, orally communicate the results of the research, think independently, construct explanations, and engage in arguments from evidence. In comparison, the RET teachers are more able to design an experiment, understand the importance of controls, make observations and collect data, and orally communicate the results of the research. They are least able to make use of the primary scientific research literature, identify a specific question for investigation, formulate a research hypothesis, reformulate he original hypothesis, write a scientific research report, and engage in argument from evidence. In addition, Ivette indicated more improvements than the other teachers in identifying a specific question for investigation, formulating a research hypothesis, designing an experiment, collecting data, interpreting the data, relating results to the bigger picture, and engaging in argument from evidence. The results also suggest that both Ivette and the other teachers showed least improvement on making use of the primary scientific research literature.

Ashlynn's Abilities to Engage in Science Practices

Ashlynn's self-reported science practices indicated that she thinks her ability to design an experiment, make observations and collect data, analyze numerical data, interpret data, develop and use models, use mathematics and engaging in argument from evidence practices did not improve from the beginning to the end of the program because her ratings for those practices were same in pre-, mid-initial, mid-now and post-surveys (Figure 9, 10, 11). Although she did an experiment for her research, she did not show much improvement in designing an experiment.

In the interview, the graduate student mentor said, "They did not really design an experiment and they were doing what I told them to do so it is hard to say that they really had a mastery of designing an experiment but I think that she could do it." Ashlynn's post interview also indicates that she did not design an experiment because she was doing what the graduate student told her to do. When I asked her whether she designed an experiment, she explained it as follows:

> Not really. I mean we did, I guess our experiment was to see how long the nitrogen cycle would take to get settled in the aquaponic system. So, I guess I mean the graduate student mentor had her project and then from that we could kind of do any anything related to water quality. So within the water quality we decided to do the nitrogen cycle, so I guess that was our experimental design. (Post interview, 8/6/2013).

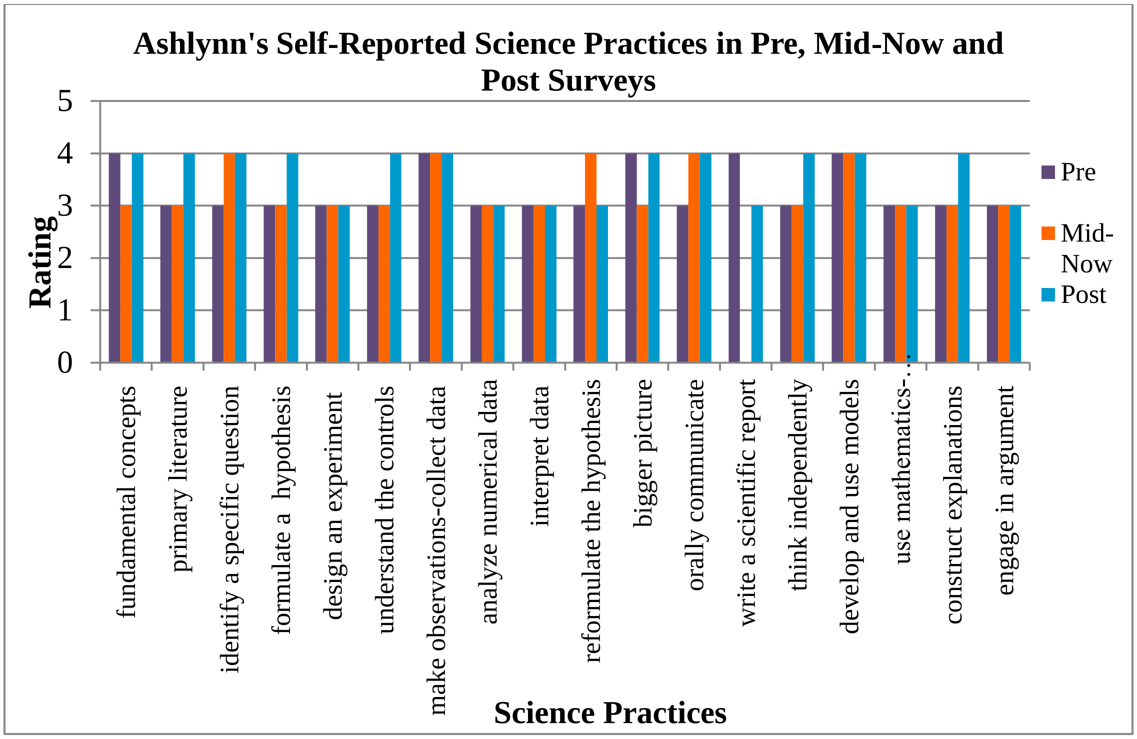

Figure 9. Ashlynn's self-reported pre, mid, and post survey ratings

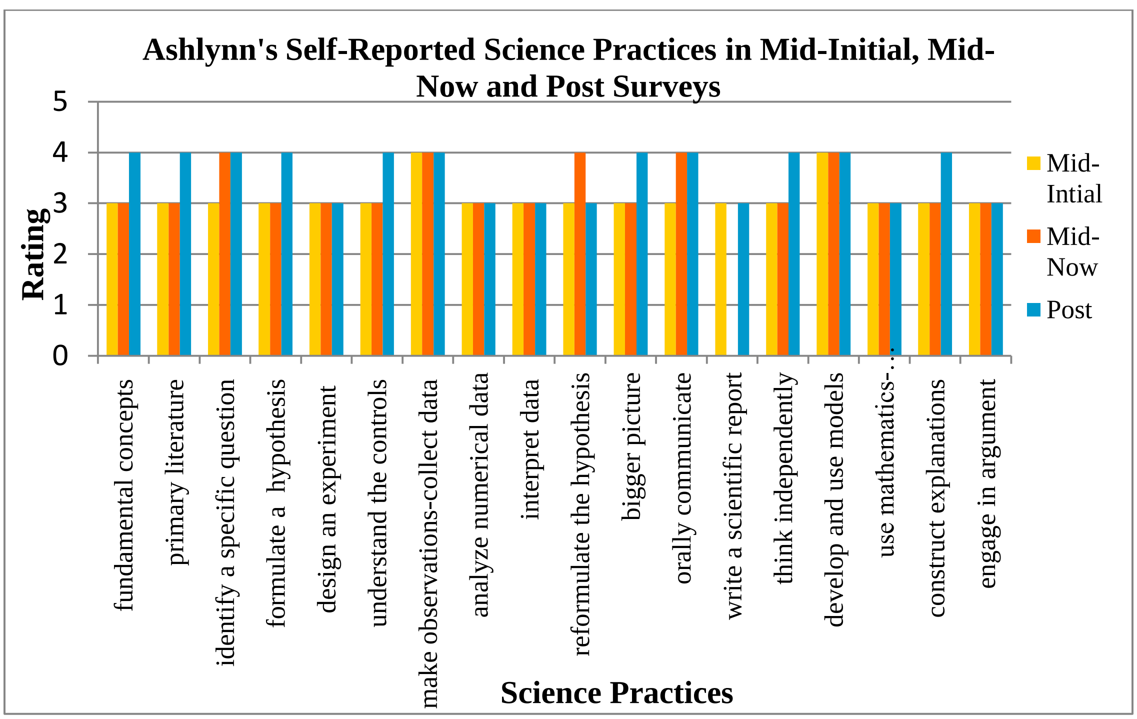

Figure 10. Ashlynn's self-reported mid-initial, mid-now, and post survey ratings

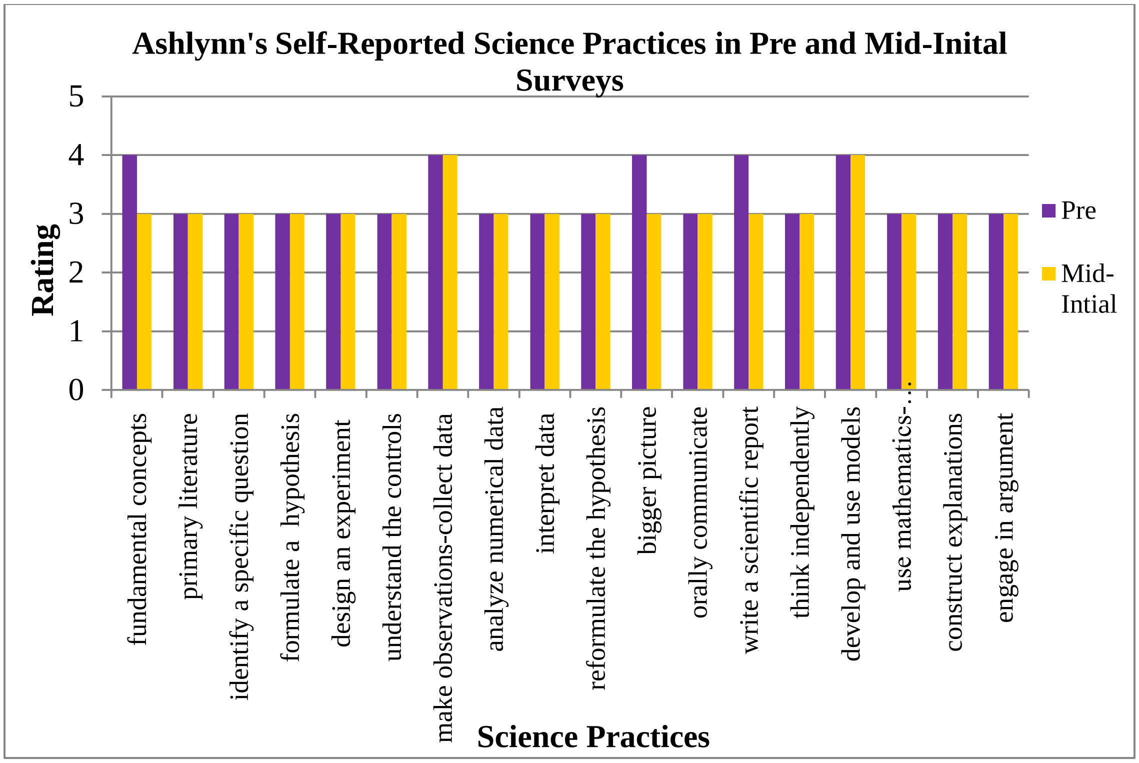

Figure 11. Ashlynn's self-reported pre and mid-initial survey ratings

When I observed her in the lab she was given a paper that has a step-by-step procedure about what she needed to complete for her experiment. Therefore, this suggests she did not get much experience about how to design an experiment; she was more following the directions.

It also looks like although her research included data analysis, she did not improve on that practice. In her interview, she explained that as follows:

> So, there is, myself and other teacher were working on the project and that is definitely not strongest of mine as being able to make graphs and completely understand the data. So, I kind of left it up to the other girl in the project to do it because she was much faster and quicker. And all of our data needed to be corrected, so there were a lot of very complicated equations involved in it and I definitely did not fully understand what was going on. And there was such a time crunch with all of this that there was not time to set-aside to really teach me. So, that was the one thing that I feel like I did not really do this

> summer that much and it is not my background and to understand it I feel like I would need a lot of help. The other girl was much faster and easier than me. (Post interview, 8/6/2013).

Her graduate student mentor also said similar things about her ability to analyze data. She said, "Analyzing numerical data, that was a little bit complicated. Ashlynn was not interested in being involved in the process, so I don't think that she improved very much with analyzing the numerical data." This suggests Ashlynn's interest and lack of knowledge about data analysis did not allow her to get experience and improve on that practice. For engaging in argument from evidence, both Ashlynn and the graduate student think she did not improve on that practice. The graduate student explained that as follows:

> And then engaging in argument, I think she knows more about the nitrogen cycle now but I don't think that she can necessarily engage in argument with someone, with a scientist that has a strong background in environmental engineering. I think as the basics, but not some of the basic fundamentals but not really strong grasp of the research areas. (Graduate student interview, 8/29/2013).

Ashlynn's ratings indicated that her ability to make use of the primary scientific research literature, formulate a research hypothesis, understand the importance of controls, think independently, write scientific report, and construct explanations practices stayed same from the beginning to the middle of the program, but they increased at the end. Her ratings for those practices were same in the pre-, mid-initial and mid-now surveys, but it increased in the post from 3-4. The graduate student ratings showed that except for the importance of controls and make use of the primary scientific research literature those practices improved very little (Figure 12).

In the interview, the graduate student expressed that Ashlynn did not have much improvement on those practices:

> Relating to the bigger picture, Ashlynn was very much task oriented, so getting to the bigger picture was not really something happened with her. I don't think that she improved very much. Writing a scientific report, they did not have to write a scientific report, so I don't think that the skills improved much in that area to the teachers. Thinking independently in one of the research areas, I don't think that Ashlynn, I think that Ashlynn could think independently but I don't think we really practiced that so I did not really see very much improvement in that. (Graduate student interview, 8/29/2013).

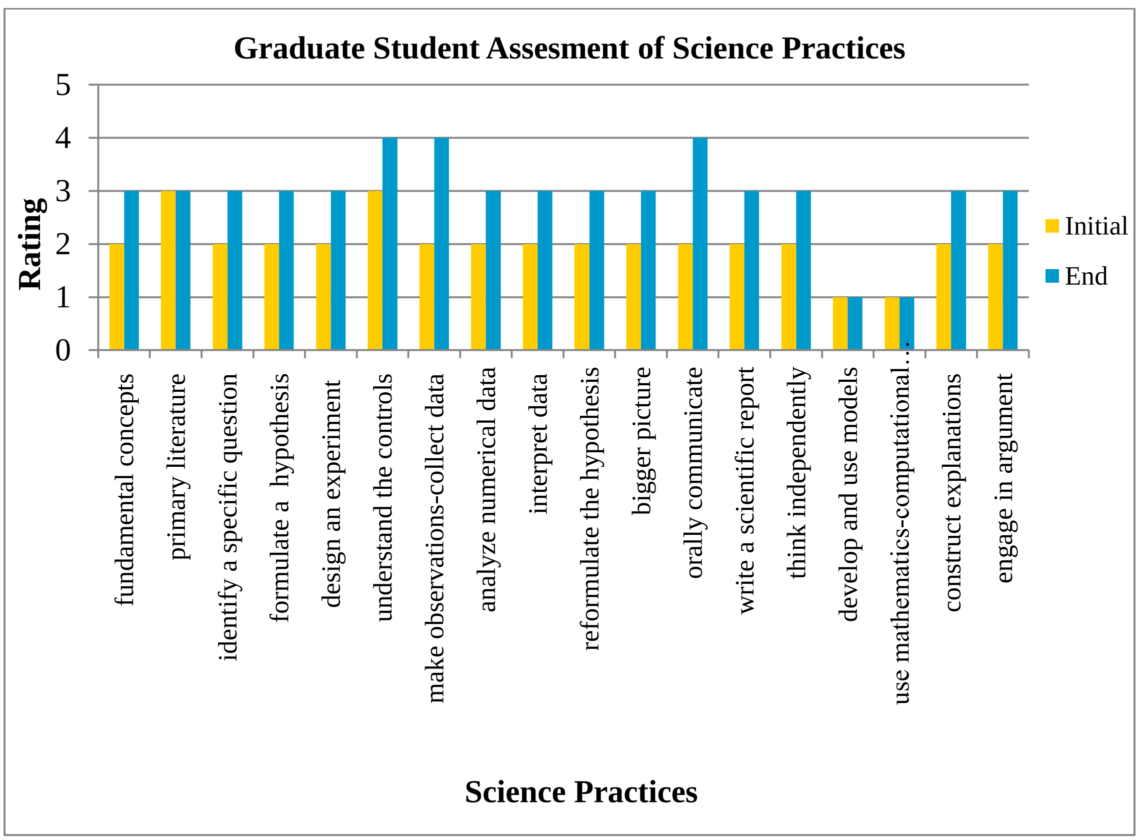

Figure 12. Graduate student survey results for Ashlynn

She also did not show much improvement on make use of the primary research literature because she could not get experience in the program. The graduate student explained that as follows:

> For using primary scientific research literature I did not really work with them to have them go look at the literature. So, I think that Ashlynn, you know, as a student was somewhat skilled with that just through her own studies but I did not see any changes because we did not really work with that. (Graduate student interview, 8/29/2013).

In the post interview, when I asked Ashlynn whether she did a literature review she expressed that she did not do so much:

> A little bit, not a ton, I kind of knew a little bit about aquaculture but not a ton and to be honest we were not given a ton of information about it. But creating our poster, we definitely read a fair amount of other research that was out there about aquaponics and books and stuff. So, that knowledge helped us to create our abstract and our background for our poster. (Post interview, 8/6/2013).

Her ratings also indicated that her ability to identify a specific question for investigation and orally communicate the results of the research increased from the beginning to the middle of the program but then it did not change. The graduate student also thinks that her ability to orally communicate the results of the research improved in the program. The graduate student survey indicated that the highest increases were in her ability to collect data and orally communication.

The lowest abilities that have no improvement in the program were to develop and use models and use mathematics and computational thinking. It looks like her ability to identify a specific question for investigation was not improved in the program very much. For instance, in my lab observations when I asked her what question they were trying to answer, she was not sure and confident she discussed with the other teacher about that. In addition, in the post interview, she could not remember her question perfectly. Her explanation was as follows:

> Yes, it was. I am not goanna say exactly right but basically, it was to figure out how long it takes to produce an effective nitrogen cycle from scratch. So, basically seeding the water that already has wasted and getting the nitrogen cycle working properly in an effective way. This is a really long question; I don't really remember exactly what this is. (Post interview, 8/6/2013).

In short, the analysis indicated that Ashlynn's abilities to engage in science practices were low at the beginning of the RET program. At the end of the program she was more able to understand the importance of controls, make observations and collect data, and orally communicate the results of research. Although Ashlynn had a little bit more improvement in collecting data and orally communicating the results of research, she did not have much improvement in the other science practices. Based on Ashlynn's and her graduate student's explanations, this might have happened either because of her interest and knowledge of engaging in science practices or the way of the graduate student manages their research. In comparison, the RET teachers are more able to design an experiment, understand the importance of controls, make observations and collect data, orally communicate the results of the research. They are least able to make use of the primary scientific research literature, identify a specific question for investigation, formulate a research hypothesis, reformulate he original hypothesis, write a scientific research report, and engage in argument from evidence. Ashlynn improved on less practices than most of the teachers, and her level of engaging in the science practices is lower than the average level of the other teachers as well.

The Results of Poster Presentations

I developed a rubric and used it to analyze the teachers' posters. The ratings in the rubric were from 1 to 4. Some teachers worked in groups during the RET program and, therefore those teachers prepared their posters together. The mean values for the items are shown in Table 23.

The analysis indicates that while teachers included more information for some science practices in their posters, they did not provide any information about some specific science practices. For instance, the teachers provided more information about designing an experiment, interpreting data, constructing explanations, and make observations and collect data than the other science practices. In addition, the teachers' ability to orally communicate the results of their research during the poster session was good compared to the other practices.

Table 23.
Mean values of ratings per each science practice in posters

Science Practices	Mean
Design an experiment	3.64
Interpret data	3.36
Constructing explanations	3.09
Make observations and collect data	3
Orally communicate the results	3
Write a scientific report	3
Make use of primary literature	2.82
Identify a specific question	2.82
Engaging in argument from evidence	2.82
Analyze numerical data	2.64
Mathematics-Computational thinking	2.64
Understand the controls	1.27
Formulate a research hypothesis	1
Reformulate the original hypothesis	1
Relate results to the bigger picture	1

The analysis also indicated that the teachers' posters still needed more information about some specific science practices since the explanations that they provided about those practices lacked information that can be included at least by proficient technicians. For instance, although all teachers provided some information about literature review in their posters as a background, the information that some teachers included was not sufficient or was not cited in the text. Only three teachers provided a sufficient amount of literature that included different articles and research reports related to the purpose of their research, and cited them as well. Also, the poster analysis indicated that only two teachers wrote their research question on the poster. The other teachers did not provide their research questions, but instead some of them included the objectives of their projects. One teacher did not include either a research question or an objective. In order to assess teachers' abilities to engage in argument from evidence practice, two questions were asked of the teachers in the interview that was done during the poster presentation. The first question was how their conclusions follow from their data; and the second question was how they think their data, results, and conclusions would be used by your professor or graduate student mentor. Only two teachers provided sufficient explanations that included teachers' reasoning to show how their data support their claim.

The analysis of the poster presentations indicated that while some teachers provided information about how they analyzed the data and used mathematics and computational thinking in their research, some teachers did not provide any information about data analysis and using mathematics. None of the teachers, except one, put information about the control of their research. This is possibly because either their research did not have controls or they did not include that information in the poster although it was used in their study.

The analysis of the posters indicates that none of the teachers provided a hypothesis or a reformulated a hypothesis in their posters. In addition, none of the teachers provided any information about how the results of their research are related to the bigger picture.

Overall, the analysis indicated that the teachers were more able to provide information about how they designed their experiment, how they collected and analyzed the data, and their interpretation of these data. In general, the teachers did not provide a question or a hypothesis in their posters; instead they wrote what objectives they had for the research. In addition, none of the posters included information about what is the relationship between the results of their research and the bigger picture. Some teachers had problems in engaging in arguments from evidence. In general, they were good at communicating the results of their research. The findings suggest that the teachers are better able to include information about the process of the research, such as the design of the experiment, and how to collect, analyze, and interpret data, rather than explaining how the findings can contribute to the literature, how they can be applied, and how to construct explanations.

Research Question 1: Overall Findings

Findings from the analysis of the pre-, mid-,-and post teacher surveys; graduate student survey; poster presentations; and individual case analysis indicated that while teachers improved on their abilities to engage in science practices, they still need more improvements on the others to be proficient at them. For instance, the teachers' abilities to design an experiment, make observations and collect data, and orally communicate the results of the research improved more than the other practices. In addition, teachers had some improvements in the practices such as understand the fundamental concepts, understand the importance of controls, reformulate the original hypothesis, relate results to the bigger picture, constructing explanations, write scientific report of research, and think independently. The analysis also suggests that the teachers who had the least improvement need more experience on how to make use of the primary research literature, identify a specific question for investigation, formulate a research hypothesis, analyze numerical data, interpret data, and use mathematics and computational thinking and engaging in argument from evidence.

In sum, the teachers' participation in the RET program helped them to improve their abilities to engage in science practices. The findings suggest that they improved on most of the science practices to some extent, but they still need more experience, knowledge, and abilities to engage in the specific practices where they had the least improvements as explained above.

Research Question 2: How Does Science Teachers' Participation in an Environmental Engineering RET Program Affect Their Understandings of Science Practices?

In order to understand how science teachers' understandings of science practices were affected after they participated in the RET program, teachers participated in pre- and post-interviews. In addition, four professors were interviewed by asking the same questions in the teacher interview. Below, I first report the findings from the analysis of professor interviews about their conceptions of science practices and the new science education Framework (NRC, 2012). This allowed me to understand what each science practice means and also to find the pre-conceived codes and themes for the analysis of teacher interviews. Therefore, professor interviews and the Framework served as a base for my analysis. Then, I present the pre and post-teacher interview analysis results separately, along with a comparison of teacher and professor understandings of science practices, the comparison of pre- and post-interviews, and overall findings of this question. In the text, the themes of each science practice that I identified in the interview analysis are written in italics.

Professors' Conceptions of Science Practices Interview

In these interviews, four professors from science and engineering departments were asked what each science practice means to them. The purpose of the interviews was to find out how professors describe and understand each practice. The findings served as a base for analysis of the teacher interviews. Below, I present the findings of each practice separately. In the first paragraph of each science practice, I present the themes I identified in the interview and explain what they mean; in the second paragraph, I constructed an overall description of each science practice from the data by putting together the analysis of the professors' explanations.

Understand fundamental concepts. Two themes were identified in the professor interview for understanding fundamental concepts practice. The first theme is *fundamental concepts of research (basic concepts, foundation, and content)*. Professors stated that these concepts are very basic in science and they are the foundation of research. For example, the concepts about a topical area such as a chemical reaction are included in that theme. The second theme is *fundamental concepts of doing research or process of research*. These concepts are the ones that are related to formulating a research question, and designing a research study with its components such as variable, control, baseline, hypothesis, and range. As such, these concepts are required to build an authentic process to investigate.

The interview indicated that for professors to understand fundamental concepts is to know the fundamental concepts of research, which are the basic concepts of the content area and required to understand the foundation of the research. Additionally, it is essential to know the fundamental concepts of doing research or the process of research which are required to build a process of what you are going to investigate. Therefore, it involves knowing the meanings of the collected measurements, baseline, controls, parameters, range, the research questions, and hypotheses.

Make use of the primary scientific research literature. Based on the interview analysis this science practice has four themes. The first theme is the *historical component and it shows what has been done before*. In this theme, professors discussed that literature provides information about what has been done or what needs to be done; therefore, it is the historical component of the research. In other words, it is the history of where the field came from, and also it is the current state of understanding about the topic. The second theme is *literature informs how to do the research or the norms of the research*. The professors explained that as literature provides information regarding what parameters should be measured in the research, it serves as a way to determine what the norm is in doing research. In addition, the literature includes information like standard physical quantities, such as boiling points of different substances. The third theme is *the literature is the baseline, platform, and first step of the research*. The professors stated it is the first step in the research to gain the knowledge and it provides a platform for the research to move forward. The last theme is *literature informs the research question and hypothesis, and it helps to find the knowledge gap*. Professors pointed out that the hypothesis and research question are identified based on the literature, and a knowledge gap is determined based on the literature to create the hypothesis or research question.

The interview analysis indicated that for professors to make use of the primary scientific research, literature serves as the basis for their research. It locates the research in the history of the field; it is used to identify what has already been found, and what questions remain. This suggests that the professors use the literature to identify gaps in the knowledge, to construct hypotheses and research questions, and provide the norms, procedures, and standard measurements that are related to the research.

Identify a specific question for investigation. The analysis of professor interview indicated that identify a specific question for investigation practice has two themes. The first one is *the research question is identified based on the literature*. Professors stressed that research question and hypothesis is determined based on what is missing in the fundamentals and what is important to answer in the literature. So, through literature review the knowledge gap is identified for the question and hypothesis. This is required because the argument has to have a foundation. It should be grounded in the literature to support why the investigation would move forward. The second theme is *the question should be clear because it is the objective of the research*. Professors explained that the research question is related to the objective; therefore, it should be clearly framed in order to investigate it.

The analysis suggests that for professors to identify a specific question for investigation is to determine a clear research question that is aligned with the objective of the study and based on what is missing in the current state of knowledge and the knowledge gap in the literature in order to have a foundation to support where it came from and why the investigation of the question is important.

Formulate a research hypothesis based on a specific question. According to the professors' explanations in the interviews, four themes were found for formulating a research hypothesis. The first theme is *literature informs the hypothesis*. The professors think that the literature serves as a base to formulate a research hypothesis. The second theme is the *hypothesis is the initial understanding of the research question* because they think it is what you expect to find in the research, and it is the assumption or the possible answer to the research question. They also think that *the research question and the hypothesis are very similar*. They said there is not much difference between a hypothesis and research question. The third theme is *hypothesis is a testable explanation* because they highlighted that the experiments are designed to test the hypothesis. The last theme is *hypothesis is good but don't try to prove it*. The professors suggest that a hypothesis provides useful guidance at the beginning of the research, but the researchers should not try too hard to prove it is right.

According to the professors, a research hypothesis is the focus of the research, a testable explanation, the initial understanding of, and the possible answer to the research question. It should be identified based on the literature and current understanding in order to have a foundation for the research. Although it is important to have a hypothesis at the beginning of the research, it is more important to be unbiased when the research is designed and when the results are interpreted to find whether the hypothesis is proved or not.

Design an experiment or theoretical test of the hypothesis. To design an experiment or theoretical test of the hypothesis consists of three themes. The first one, *the design is the steps to follow for the research*, means to develop a series of aims to test the hypothesis. The second one is *experimental design is based on to support or reject the hypothesis*. Professors explained that a valid experimental design has to either support or reject the hypothesis. In other words, it means to be able to answer whether the hypothesis is valid or not. The last theme is *the design should not depend on only the hypothesis*. The professors suggested that to have a hypothesis at the beginning of the experiment might be helpful, but the researchers should not force the research or the data to support or to reject it.

The interviews indicated that for professors to design an experiment means to determine the steps to follow during the research and to identify all the variables to see the impact of one variable on another in order to either support or reject the hypothesis. The design of a valid experiment should not be a hundred percent hypothesis driven; the scope of the experiment should be bigger than the specific hypothesis.

Understand the importance of controls. Professor interviews indicated that to understand the importance of controls, practice can be divided into four themes. The first one is *controlled variable and control are different*. The professors made the clear distinction between the control and controlled variable. Basically, a control is like a baseline in the experimental design. In the experiment, when you see something changes due to something if you don't have a baseline to compare it is difficult to come up with the conclusion. Controlled variable is the variable that is constant during the experiment. For instance, you can keep the temperature constant in the experiment; that means the controlled variable is the temperature. In the second theme, *control is the baseline of the research*, professors pointed out that it helps to compare and come up with the conclusion. The third identified theme is *control helps to compare*. It is like a reference point for comparison. Finally, the fourth theme is about whether *the control is always important*. Some professors think this is very important because it is central to everything they do, but some of them mentioned that if the research does not need to have a control then it is not important. Therefore, we can say that its importance depends on the type of the research.

According to the professors, understanding the importance of controls means to know both the meanings of controlled variable, control and their difference and to see how control serves as a baseline for comparison in order to come up with a conclusion. Also, it is important to be able to decide whether it is required to use them in the research depending on the nature of the investigation.

Make observations and collect data. The analysis indicated that make observations and collect data practice has five major themes. The professors' answers were more focused on the difference between observation and data collection. In the first theme, *observation and data collection is different,* they stated that data collection is more related to gathering numbers, measuring variables and information, and making observations is more visual and it is to observe the things related to the research. The second theme is *observation is about the quality and validity of the experiment and helps to troubleshoot the problems.* They explained that observation allows seeing whether or not something looks funny in the experiment or there is something that went wrong in the experiment. Also, it helps to find solutions for the problems that may arise during the research. They said it is more about the quality control of the experiment and helps to inform whether the experiment is valid. In the third theme, *observation is qualitative and data collection can be quantitative,* they expressed that making observations is qualitative and collecting data is quantitative for some disciplines like engineering and science. The fourth identified theme is *data collection and observation should be unbiased, objective and accurate.* Professors suggested that observations should be as accurate as possible; and researchers should be as objective as possible because making unbiased and systematic observations is very important.

The professor interviews indicated that there are differences between making observations and collecting data. While collecting data is related to gathering qualitative or quantitative information, making observations is more related to the quality control of the research. Making observations helps one to realize the problems and to see what went wrong in the research and find solutions to them. Although making observations and collecting data are different, they should both be unbiased and accurate in order to conduct reliable research.

Analyze numerical data. The analysis of the professor interviews indicated that to analyze numerical data practice has five major themes. The first theme is *to find a trend in the data*. Professors expressed this means to see a similar trend across different entities by using statistics. In the second theme, *to use statistics to describe a physical system*, they think that mathematics can describe a physical system and it is used to determine how a physical system is behaving. In other words, mathematics is used to determine how a system can be represented in a world. The third theme is *to compare control and treatment samples to see a statistical* *difference*. They said this means to compare multiple experiments across multiple times and to compare the quantitative endpoints across controls and treatments samples. The fourth theme is *to find the power of the results*. They expressed this means to determine whether it is valid and whether the standard deviation is statistically different or not. The last theme is *data analysis is related to the hypothesis and the purpose of the research.* The interviewed professors think that the analysis of the data should be done based on the purpose of the research.

To analyze numerical data means to use statistics to determine whether or not there is a trend in the data, to describe how a physical system is behaving, and to make comparisons of the treatment and control samples or experiments in order to find out whether they are statistically different or not. Data analysis should be compatible with the goal of the study and the hypothesis; it is more looking at the power of the results and provides information about the statistical power of the number of replicates in the study.

Interpret data by relating results to the original hypothesis. The analysis of the interview indicated that interpreting data by relating results to the original hypothesis practice combines three themes. The first theme is *to determine whether the data and results support the hypothesis*. The professors think that researchers determine whether the experiments have met the hypothesis. Also, they think that researchers collect the data to see whether the hypothesis is supported or not. The second theme is *if the results don't support the hypothesis you need to modify it*. This theme means if data analysis doesn't match with the hypothesis you should go back to literature review and your analysis and modify the hypothesis or generate a new hypothesis to move forward and address particular points. The third theme is *if the results don't support the hypothesis the researcher needs to explain why your results are like that*. Therefore, this means it is trying to get inside of the results and explain the reasons of why they were obtained.

For the professors, interpreting data by relating results to the original hypothesis means after data collection looking at the data in order to find out whether the data support the hypothesis. In the case of when the hypothesis is rejected, it is the ability to explain the reasons for why the hypothesis does not match with the data, and based on the explanations it is to make decisions about what modifications that should be done in the hypothesis or in the research process.

Reformulate the original hypothesis. In the data analysis, two themes emerged related to reformulating the original hypothesis science practice. The first one is *if the data do not support the hypothesis it is to produce a new one.* This means if the data do not match with the hypothesis it should be reformulated to address a different aspect of the question. Therefore, it requires going back and coming up with a different explanation. As part of the second theme, *the researchers should be prepared to reformulate the hypothesis*, the professors suggested that researchers should be flexible to reformulate the hypothesis, and the scope of the research should be bigger than the original hypothesis when there is a need to reformulate it.

The interviews suggest that for professors to reformulate the original hypothesis is interpreting the data in order to come up with a different explanation of the results, and creating and testing a new hypothesis when the data do not match with the original one. This means the researchers should be ready to reformulate the hypothesis based on their data by designing research which provides the opportunity to reformulate and test different aspects.

Orally communicate the results of research. To orally communicate the results of research has three themes. The first identified theme is *to communicate the research in national* *meetings.* In these meetings the researchers transmit the knowledge in a short amount of time to a large audience who can be critical about the study. The second theme is *oral communication helps to see the new ideas and to make sure the research has no mistake*. Professors stated that it gives you the opportunity to get out of the box, helps to bring fresh ideas to the research and helps to make sure there is no obvious mistake that is made. And the third theme is *to communicate about the research to other people*. This theme represents informal discussions, such as weekly lab meetings that people talk about the experiments and the conversations with a peer about the problems that the researchers are having in the research.

Based on interview analysis, for the professors to orally communicate the results of research is being able to speak about the research in a way that is understandable to a discipline-specific audience at a higher level in national or international meetings such as conferences or symposiums, as well as in informal settings such as lab and research group meetings. Orally communicating the research with other people helps to see different views which may lead to realizing possible problems and solutions to them.

Relate results to the bigger picture. The professor interviews indicated that to relate results to the bigger picture practice has three themes. The first one is *the contribution of the research to the literature and research field*. The professors think this means to explain how the research findings contribute to the topical area, what the implications of the research are, how the findings advance the field, and how the research findings contribute to the knowledge gap in the literature. The second theme, *the application of the research findings*, means to explain how the findings of the research can be applied to a situation, such as in a community. And the third theme is *adding new knowledge* which means to find new information and apply that knowledge to something that may advance the field.

The analysis indicated that for professors to relate results to the bigger picture means to provide explanations about how the research makes contributions to the research field and literature by adding new knowledge that can advance the field. In addition, the researchers should be able to explain in what ways the findings of the research can be applied to a problem situation in society in order to provide possible solutions.

Write a scientific report of research. Based on the professor interview analysis, to write a scientific report of research consists of four themes. The first one *is the report needs to have some important components* including a good background; a summary; methodology to define the research; an introduction to discuss current state of knowledge; data, observation, and findings; the question that you are asking; and an objective that you are trying to achieve. In short, the report needs to document the scope of the research. The second theme is *to communicate the research so other people can understand or replicate it*. This means to communicate the research to a broader audience to help them to understand it. In the next theme, *a scientific report has a technical or specific format,* they said scientific reports are written in a professional and technical form. And the last theme is *the purpose of the report is to inform or move the literature/field forward.* Professors highlighted that reports can contribute to the research field and make improvements in the research area.

The professor interviews indicated that the purpose of the research report is disseminating knowledge in a specific format that includes the summary, background, purpose, design, results, and conclusions in order to provide information to the people who are interested in the study. For professors, scientific reports that have new findings move the field forward, and the ones that do not have new findings inform the literature. They think that the report can be written and submitted to a very high-tier journal because it has a new finding and is going to move the field forward. Subsequently, a researcher can go back and look at that experimental question in order to understand why something happens, how it is different and why it has different kinds of conditions. The reports that present those kinds of information inform the literature, and therefore they are important as well.

Think independently about the research area. Based on the analysis, six themes were identified for think independently about science practice. The first one, *to be able to go through the research process by yourself*, means to take the ownership of the research process, including identifying the topic to come up with the hypothesis and question based on the literature; to design a valid experiment to support or reject the hypothesis; to do a literature review; to put all the research together and think beyond it; and to disseminate the knowledge generated by yourself. The second identified theme is *to be able to think critically*. The professors mentioned that to think critically is more important than to think independently because it helps to be able to make a critical decision about the research. In the third theme is *to be able to see the connections between different components*, they think that an independent researcher can identify what kind of connections there are between the components of the research. The fourth theme is *to be able to think what is missing and what is next*, relates to the ability to predict what may occur where you see the connections based on your practice and to think outside and beyond the scope of the experiment that someone has done. The fifth theme is *to be able to explain why a phenomenon is working or not working*. Professors pointed out that this means to explain why a phenomenon is happening in the research without getting help from other people. And last theme is to *make a contribution by doing a new research*. This theme means not to repeat what other people have done and to contribute to the research what is missing in the literature.

Based on the interviews, the professors considered that to think independently is to be able to take the responsibility of the overall research from the formulation of the idea or the hypothesis to the dissemination of the knowledge; to look for connections and trends in order to see how the research process might be affected; to think beyond and predict what may occur; to make critical decisions about the research based on your observations and what other people have done; to think about what might be the reasons of the problems that occur during the research and to find the solutions by looking at the literature and repeating the process without getting help from other people; and to produce new knowledge that can make an important contribution to the research field.

The practices that are presented above were adopted from Kardash (2000). Although those practices are closely related to the practices that are in the new science education Framework, the phrasing of the expressions are different. Therefore, the professors were asked what each of those practices mean, since the literature did not have any information about the explanations of them. In addition to those practices, below I present four science practices that come directly from the new science education Framework (NRC, 2012). In the professor interview, firstly the professors were asked the practices that were adapted from the Kardash (2000) survey. Secondly, they were shown the list of science practices that were published in the Framework, and they were asked how they think the science practices are the same or different from the set of skills that were adapted from the Kardash (2000) survey. All the professors expressed that they did not see any differences between the science practices in the Framework and the research skills in the Kardash (2000) survey. They were then asked what each science practice in the Framework meant to them. Since they already answered the questions about the research skills, and they thought that there were no differences between the science practices and the research skills, they provided very short explanations and few details for the science practices when compared to their explanations for the research skills. For this reason, I analyzed the Framework rather than the professors' shorter explanations for the four science practices in order to provide complete descriptions, to find out what these four science practices mean, and what characteristics they have.

Develop and use models. Five themes were identified for develop and use models practice based on the analysis of the Framework (2012). The first one is *models represent a system*. In the Framework it is stated that models explain current understandings of a system or parts of a system. The second theme, *they allow better visualizing and understanding a phenomenon,* means that models are visual tools that help to understand the phenomenon being studied. The third identified theme is *they help to understand and think about science and make sense of the experience*. Models help to develop a possible solution to a design problem and they are tools for thinking. In addition, they lead to a deeper understanding of science and enhanced scientific reasoning. The next theme *is they allow predicting the behavior of systems*. This means models help to predict what will happen in a system. And the last theme is *they bring certain features but they don't correspond exactly*. The Framework points out that the range of the validity of their application and the precision of their predictive power is limited.

Based on the Framework (2012), models are explicit representations that are in some ways analogous to the phenomena. Although they do not correspond exactly to the more complicated entity being modeled because they cannot bring certain features into focus while minimizing or obscuring others, they help to visualize, predict the behavior of the phenomena, deeply understand the science, and improve scientific reasoning.

Use mathematics and computational thinking. The analysis of use mathematics and computational thinking practice includes three themes. The first theme is *to analyze data sets*. The Framework (2012) states that mathematics and statistics are used in the analysis of large data sets. The second theme, *to visually represent the data*, means to view data from different perspectives and with different graphical representations. The third theme is *to identify relationships and patterns between the variables and data*. According to the Framework (2012) mathematics and computational thinking is used to search for distinctive patterns and identify relationships and significant features in ways that were previously impossible.

The analysis of the Framework indicates that mathematics and computational thinking is used to statistically analyze the data and present it in visual forms such as graphs, charts, tables, and figures. They are used to test relationships between variables and to express relationships and quantities in appropriate mathematical forms.

Constructing explanations. In order to find the themes related to constructing explanations practice, the Framework (NRC, 2012) is analyzed. The analysis of the Framework indicated three themes for that practice. The first one is *to develop explanations based on data, evidence, models and observations*. This means to construct explanations of phenomena using knowledge of accepted scientific theory; developing explanations of phenomena based on observations or models with the aid of models, representations, data and evidence; and also use primary or secondary scientific evidence and models to support or refute an explanatory account of a phenomenon. The second theme is *to explain the relationships, cause and effects between the variables*. As stated in the Framework (NRC, 2012), this means to offer causal explanations appropriate to their level of scientific knowledge and describe the mechanisms that support cause and effect inferences about the variables. The third theme, *to identify the gaps, weaknesses in the* *explanations,* means to have the ability to find out the strengths and the weaknesses of the explanations and knowledge gaps.

Based on the Framework (NRC, 2012), explanations are constructed by using scientific theories, models, representations, data, observations, and primary and secondary evidence in order to support or not support the arguments about phenomena. In addition, explaining cause and effect relationships between the variables, evaluate and critique the explanations of their own or those of others, and finding the strengths and weaknesses of them are also important to construct meaningful arguments.

Engaging in argument from evidence. The analysis of the Framework (NRC, 2012) indicated that engaging in argument from evidence practice consists of two major themes. The first one is to *use reasoning and to justify or support a claim.* This theme is a combination of using reasoning and argumentation to make the case, making a justified claim about the world, and constructing a scientific argument showing how data support a claim. The second theme is *to make critical judgments and to find strengths and weaknesses of the arguments*. This means to use critique and evaluation to judge the merits of any scientifically based argument; identify possible weaknesses in scientific arguments; explain the nature of the controversy in the development of a given scientific idea; and how claims and knowledge are judged by the scientific community today.

The analysis indicated that to engage in argument from the evidence is to use argumentation and reasoning skills to make a justified claim about a scientific phenomenon or data to show how it supports a claim. In addition, it is becoming a critical consumer of science by using opportunities to use critique and evaluation to judge the merits of any scientifically based argument; and identifying flaws in the arguments, and modifying and improving them in response to a criticism.

Teachers' Understandings of Science Practices Pre-Interview

In order to understand teachers' understandings of science practices they were interviewed before the RET program started. The purpose of this interview was to find out what each of the science practices meant for teachers before they participated in the environmental engineering RET program. Below, I present the analysis of each science practice separately. In the first paragraph of the explanation of each science practice, I present the themes that were identified in the pre-interview and what they mean for the teachers; and in the second paragraph, I created a description of each theme by putting together the teachers' explanations of the themes. Then next paragraph compares the teachers' understandings with the professors' explanations.

Understand fundamental concepts. The analysis of the pre-interview indicated that teachers have four main themes for understanding the fundamental concepts practice. The first theme is *to understand the basic information and foundation of the subject*. They think that understanding fundamental concepts means to understand the basic scientific understanding, the foundation and solid structure of what you are doing, to know the things related to the content, and to understand the fundamental ideas in the subject. The next theme is *the basics and foundation of the teaching subject.* They think the topic that they teach also constructs the fundamental concepts. In the next theme, *to know the new information in the subject,* they stated that being up to date and aware of the new research and findings provides information about fundamental concepts. And the last theme is *to understand how science is done*. One teacher stated that fundamental concepts are needed to conduct the research process.

The pre-interview analysis indicated that for teachers to understand fundamental concepts is to know the fundamental ideas of the subject area in the research or teaching, the basic knowledge that is related to the content that you are working on, and the concepts that are newly constructed. One teacher thought that it means to have the knowledge of the components of the research that helps to design the investigation.

The comparison of professors' and teachers' understanding of fundamental concepts indicated that teachers' understandings are incomplete. Although the professors' answers combine the concepts that are important to have the foundational knowledge of the subject area and the concepts that are required to build an authentic research, teachers' understandings are only related to the knowledge of the content. Only one teacher stated the concepts of doing research. Therefore, teachers' understandings of fundamental concepts do not include one of the most important components related to doing research.

Make use of the primary scientific research literature. In the pre-interview, three themes were identified for teachers' understandings of making use of the primary scientific research literature. The first theme is *journals, articles, books, and peer reviewed publications are primary scientific research literature*. Teachers think that primary scientific research means to read and understand journals, publications, research articles, and peer-reviewed articles. They also mentioned that textbooks or research literature for curriculum development is a kind of primary scientific research literature as well. The second theme is *to see what has been already done*. They think that previous research helps to learn what already have been done, to build on the basic knowledge, and what we already have as a background. The third theme is *to use the literature in order to form opinions, to apply and to solve a problem*. Teachers think that primary literature helps to build on current articles to form opinions, to interpret what is going on, and to adapt and use it to solve a problem or apply it to something.

The analysis of the pre-interview indicated that for teachers to make use of the primary scientific research literature is to read and understand the publications such as articles and books in order to learn what has been done before and to have a background about the research. In addition, teachers think that literature is used to learn the important information that can be used for problem solving and application of the ideas.

The comparison of the teacher pre-interviews and professor interviews indicates that teachers' understandings of making use of the primary research literature is more related only to reading and having a background about the research, but they do not explain how they will use that background in their study. On the other hand, while the professors provided information about the usage of the literature such as in constructing the research question, hypothesis, and knowledge gap (or finding the norms, procedures or standard measurements), the teachers' understanding did not provide those explanations. Although both teachers and professors think the literature is used to identify what has been done before, the teachers' understandings do not show the idea of using the literature to find what is missing in the area of the research.

Identify a specific question for investigation. Four themes were identified for teachers' understandings of identifying a specific question for investigation practice in the pre-interview. The first one is *to find a specific area, problem or issue*. The teachers think that to identify a question is related to finding a problem situation or an issue for the research. The second theme is *to focus or narrow down the research*. They think that to narrow down the problem helps to focus on a certain area. Also, they specified that it means to limit the subject to a hypothesis and to select a single element within a complex system. The third theme is *to identify a question to* *investigate, find answers, to change in order to have more understanding*. Teachers mentioned that this means to identify an issue or a concern that needs to be changed, to find something specific that you want to investigate, and to identify a problem to change the current way of thinking. The fourth theme is *to identify a topic that needs to be answered and benefits the society*. They said this is related to choosing a contemporary topic that benefits society, and to come up with a question about a contemporary topic.

Based on the pre-interview for teachers, a specific question for investigation is to determine a problem situation or an issue in order to narrow down and limit the area of the research. They think the research question may be an issue or a concern that needs solutions, an interest of the researcher to investigate, and an issue that may change the current understandings or help to society to overcome a problem.

Teachers' understandings of identifying a specific question for investigation indicated important differences compared to the professors' explanations. The first one is for professors, who stated the research question is identified based on the literature and knowledge gap, but none of the teachers made the connection between the identification of the question and the literature. Second, for professors the research question is aligned with the objective of the study, but the teachers only think that it is a problem situation or an issue to narrow down or limit the area of the research. This suggests the teachers do not see the connections between the objective of the study and the research question. Although the teachers make connections between the research question and a problem situation, they do not explain how they can come up with that problem. On the contrary, for professors it is identified based on what is missing in the current state of understanding and knowledge gap in the literature.

Formulate a research hypothesis based on a specific question. Four themes were found in the pre-interview based on the teachers' understandings of formulating a research hypothesis based on a specific question practice. The first theme is *a research hypothesis is the potential answer to the research question or a prediction*. Teachers think that hypothesis means what the potential answer of the research question could be, the prediction of the expectations about what is going to happen in the research, and coming up with what you think will happen. The second theme is *the literature informs the research hypothesis*. Teachers mentioned that a literature review should be done to make sure the hypothesis has not already been investigated. The other themes are *it means to use prior knowledge to come up with an idea* and *its format is an if-then statement*. Some teachers said the format of a hypothesis is an if-then statement, and some of the teachers said it shows how one variable affects the other variable.

The analysis of the pre-interview indicated that for teachers a hypothesis is an if-then statement which shows the cause and effect relationships between the variables and an expectation which shows what is going to happen in the research and what could be the answer of the research question. They think that the hypothesis is identified based on the literature that explains what has been done before and the background knowledge about the research.

The comparison of the teachers' and professors' explanations about formulating a research hypothesis indicates that both teachers and professors think a research hypothesis is related to the answer of the research question. While professors think that it is the possible answer of the question and an assumption, teachers think it is the expectation of the answer to the question or the potential answer. One of the differences is the teachers' understanding of hypothesis is more related to the structure of the statement. For instance, while for teachers a hypothesis is an if-then statement that shows a relationship between variables, the professors think the hypothesis is a testable explanation.

Design an experiment or theoretical test of the hypothesis. The teachers' understandings of designing an experiment practice consist of four themes as identified in the pre-interview. The first theme is to *design an experiment means to determine the steps to follow in order to answer the question*. They think this means to design a way to find out what you are looking for, and to create a process to show the effects of one variable to the other and to design a step-by-step process to find the answer of the research questions. The second theme is *to find the methodology.* The teachers stated that the research design should have a method; therefore, it needs to be identified. The next theme is *to set up an experiment to test the hypothesis*. Some teachers stated that an experiment is designed to see whether the hypothesis is supported or not. And the last theme is the *design needs to have a control and variables*. The teachers explained that the researcher should decide what variables and controls will be used in the research.

The analysis of pre-interview indicates that for teachers to design an experiment is to determine the step-by step procedure or a way to follow that includes the methodology, hypothesis, and the controls and variables in order to answer the research question or to test the hypothesis.

The analysis indicates that both teachers and professors think that designing an experiment is to identify the steps or a way to follow in order to answer the research question or to see whether the data supports the hypothesis. To determine which variables should be included in the research is stated by both professors and teachers. Although teachers and professors mentioned the research is designed to test the hypothesis, the professors also emphasized that the design should not be too dependent on the hypothesis because this may cause problems. For example, some researchers may try to prove their hypothesis by changing the interpretation of the data. Therefore, the scope of the study should be flexible to change the hypothesis or modify the research. Teachers did not state that situation in their explanations. Their explanations are more related to the overall structure of the design, instead of the important components of a valid research.

Understand the importance of controls. In the pre-interview, the teachers' understandings of controls have seven themes. The first one is it is *the baseline and foundation*. They think that control is the baseline that shows the normal conditions and the foundation to see whether there is an error in the experiment. The second theme is *it helps to see the effects, differences, and changes in the experiment*. The teachers think that control helps to see what is influencing on one thing, helps to see whether the change is due to one specific variable, and it is something that is tested against to see what the differences would be. The third theme is *it makes the data more reliable and minimizes the different factors*. This means controls help to minimize the effects of different factors on the research outcomes; therefore, it is something to fall back on and makes the data more reliable. The fourth theme is *control is something that stayed the same*. Teachers think that control is consistent, standard, and not changed; therefore, it stays same in the experiment. As part of the fifth theme, *it helps to compare*, they think that control helps to compare to see whether an effect was seen during the investigation so it provides comparable data. The sixth theme is *controlled variable*. Some teachers stated that these are the variables that are held constant and limited. Finally, the seventh theme is *the control group*. Some teachers think that control is to keep all parameters and conditions constant.

The analysis indicates that for teachers control is a baseline to see whether there is a change or difference in the experiment; therefore, it allows making comparisons. In addition, they think that control is something that stays constant and consistent during the experiment; therefore, it provides comparable data. Although the teachers' answers and explanations included both controlled variable and control group, they only used the word "control" instead of "controlled variable" or "control group," and they did not make clear distinctions between them.

The teachers' understandings of controls indicated some similarities with the professors. For example both teachers and professors stated that control serves as a baseline for the study in order to make comparisons in the data. Although both the teachers and professors talked about control variable and control group, the teachers did not make clear distinctions between them. Some teachers talked about control variable and some of the talked about control group, but they did not specifically mention how they are different. In comparison, the professors specifically stated that control and controlled variable have different purposes. In addition, although most of the teachers think that control is very important in the research, the professors pointed out that the importance of control depends on the purpose of the research because some studies do not require using controls.

Make observations and collect data. Based on the pre-interview analysis, teachers' understanding of making observations and collecting data practice is divided into seven themes. The teachers think that to make observations and collect data means *to gather qualitative and quantitative information*. They think this means to collect both qualitative and quantitative information in the research. The second theme is *to see whether the hypothesis is correct*. The teachers expressed that data collection and observation is done to see whether the hypothesis is supported. The third theme is *to take measurements and record the observations*. They stated that recoding the measured variables and the observations is very important. In the fourth theme, *to view and watch the system to see what is happening*, they think that to view the process of the research and watching how things happen is part of that practice. The fifth identified theme is *using the senses to gather data*. They explained that it means to purely use your senses and gather the information that is collected by the senses. The sixth theme is *they are not making inferences*. One teacher mentioned that to make observations and collect data is not to make inferences. The last theme is *observations should be unbiased*. Some teachers stated that the observations should not be biased and should be as objective as possible.

The pre-interview analysis indicates that for teachers to make observations and collect data is to take measurements and collecting qualitative and quantitative information and recording them in order to find out whether or not the hypothesis is supported by the data or to see what is going on during the investigation by using the five senses, such as smelling, seeing, and touching. One teacher mentioned observations provide different information because they are not inferences; they are related to actually seeing what is happening in the research, and therefore they should not be biased. For instance, she thinks that the observation should be done in a specific time by the same person to keep the consistency because different people can see the things in different ways and it may not be the same.

The analysis indicates teachers' understandings do not explicitly show the differences between making observations and collecting data, but the professors emphasized those differences, such as observation is more related to quality control of the experiment and seeing if there is a problem in the experiment and trying to solve the problems; whereas data collection is more related to gathering quantitative and qualitative information. The teachers do not emphasize those different features between data collection and observation. The analysis also indicated that one teacher and the professors think making observations should be unbiased. While the teacher thinks the observation should be unbiased by keeping the consistency, the professors think the observations should be done systematically and unbiased.

Analyze numerical data. The teachers' answers in the pre-interview indicated that their understandings of analyzing numerical data practice have five themes. The first one is *to put the data into graphs, charts, and spreadsheets*. The teachers think this means to create graphs and charts in order to find relationships between the variables. In the second theme, *to find a trend or pattern*, the teachers stated that data analysis is done to see whether there is a trend or pattern in the data. The third theme is *to use statistics in order to find correlations, averages, and comparisons*. They think this means to compare the data to see whether they are statistically meaningful and to find the averages in the data. The fourth theme is *to find why the data (not) showed the expected measurement*. The teachers stated that this means to find out whether the data is in favor or going against the problem and explain why the data did not show the expected or unexpected measurements. The fifth theme is *what the data mean or make sense*. This means to explain the data that is collected and what it means and to make sense of the measured experimental values.

The pre-interview analysis indicated that for teachers, data analysis means to find what the data means, and to find a trend or a pattern by using statistics such as averages and comparisons by using some visuals such as graphs, charts and tables. They also think that data analysis requires uncovering the reasons if the data do not show the expected results.

Although both teachers and professors think that to analyze numerical data is to find a trend or pattern in the data, there are some differences in the explanations. Teachers limited their explanations of statistical analysis to calculate the mean or average, but the professors are more focused on whether or not the data are statistically different. Both teachers and professors stated that data analysis includes comparisons, but teachers do not explain how they do the comparisons. The professors explained it as comparing treatment and control samples. In addition, the teachers' do not make the connections between the data analysis and finding the power of the results. On the contrary, the professors highlighted that the purpose of the data analysis is to find out the power of the results. This suggests teachers' understanding of the data analysis is more related to what kinds of techniques are used, but professors also explain how and why they are required.

Interpret data by relating results to the original hypothesis. Four themes were identified for teachers' understandings of interpreting data by relating results to the original hypothesis. The first theme is *to see what is coming out of the data.* They think this means to explain what the data mean and what patterns are found in the data. The second theme, *to determine whether the data and results support the hypothesis,* relates to the teachers' belief of what it means to collect and analyze the data to see whether the hypothesis is correct. The third theme *is if the results don't support the hypothesis you need to modify it.* It means after looking at the data you need to go back to the hypothesis and see if it needs to be revised or requires further testing. The fourth theme is *to think why the expected or unexpected results are gotten*. The teachers think this means to explain the reasons if the results are different than the expected values; to explain the reasons of the sources of errors in the research and to see if there is a correlation behind any changes based on what you subjected.

The analysis of the pre-interview indicated that for teachers to interpret data is to explain what the data mean, how it is related to the hypothesis, and what the results of the research are. In addition, they think that it means to be able to provide the reasons why the data and results did not match with the original thoughts and to make the necessary changes in the hypothesis.

Teachers' understandings of interpreting data by relating results to the original hypothesis indicated alignment with the professors' explanations in terms of what data interpretation means and how it is related to the hypothesis. Both teachers and professors think that interpretation also includes the ability to explain why the expected results are or are not achieved and to provide the possible reasons for them. In addition, teachers think that it is important to change the hypothesis if the data do not support it. That component was also stated by the professors. This suggests teachers' understandings of interpret data practice indicated similarities with the professors' explanations.

Reformulate the original hypothesis. Teachers' pre-interview analysis indicated that their understandings of reformulating the original hypothesis have four themes. The first theme is *to change the hypothesis when the data and results do not support it*. The teachers explained that if the data analysis does not answer the question it is required to go back and reword it or a new hypothesis should be created. The second theme is *to make more experiments and testing*. Teachers mentioned that when the data goes against the hypothesis it is required to see whether it needs more experimentation and data collection. They think it is to make more experiments, collect more data, and analyze and reinterpret them. The third theme is *to modify the hypothesis and question to get expected results*. Some teachers think that if the first hypothesis did not work the researcher needs to go back to get the expected results. And the last theme is *to find another way or new idea*. They explained that it is to find another way if the first hypothesis is not viable or not possible to prove, and so it means to restate the original topic to refine the direction of the new research.

The pre-interview analysis indicated that for teachers to reformulate the original hypothesis is to modify the hypothesis or find a new one when the data do not match with the original explanation in order to find the expected results. It also means to find a new idea if the original hypothesis cannot be proved in order to change the direction of the research.

Teachers' understandings of reformulating the original hypothesis indicated both teachers and professors focus on the relationship between the hypothesis and data. They think if the data do not match with the hypothesis it should be modified. Although the professors' explanations emphasized the importance of the preparedness of the researcher and the design of the research, because in order to make changes on the research it should be flexible, none of the teachers stated those explanations.

Orally communicate the results of research. The teachers' answers suggest that their understandings of orally communicating the results of research have four main themes. The first theme is *to answer questions about the research.* They think that it means to answer people's questions about the research. The second theme, *to give a presentation in a scientific community such as a poster presentation or a conference,* indicates teachers think that presenting the research in a conference to a scientific community is a kind of oral communication of the research. The third theme *is to talk about what needs to be changed or redone.* They think this means to talk about what should be redone if there is a problem and to communicate with people to figure out what works and does not work in the research. The fourth theme is *to talk about and defend the results of the research*. They mean to defend the evidence that supports or rejects the research, to explain how the results fit into the bigger picture, and to publish the results in order to help the scientific community.

Pre-interview analysis indicated that for teachers to orally communicate the results of research is to speak about the research, defend the results by using evidence, and answer the questions about the research in a scientific community such as in a conference by giving a presentation or making a publication. They also think it helps to realize the possible problems in the research and what should be modified in the study.

The analysis suggests teachers' understandings focused more on the formal meetings rather than the informal settings. Teachers think that the results of research can be communicated in a conference or a poster presentation. For professors, oral communication can be done in formal settings such as conferences, symposiums, national and international meetings, or in informal settings such as lab or research group meetings. For some teachers and professors, oral communication of the research provides opportunities to realize possible problems of the research and their solutions, but this explanation was not given by all the teachers. Although teachers' understandings do not show the importance of the level of the language during the communication, the professors stated that it is important to speak about the research in way that is communicable to the professionals at a higher level.

Relate results to the bigger picture. Based on the analysis of the pre-interview four themes were identified for teachers' understandings of relating results to the bigger picture practice. The first identified theme is *how the research affects the field and how it relates to the whole*. According to the teachers, this means to explain how the research affects the entire role in the field, using the results of one part of the research to help with the final goal of the whole research, and the specific research is the part of the whole research for improvement. The second theme is *how the research affects globally*. Teachers think this means how the results affect more than just the research itself; research affects local, national, and global scale; and how the research relates to the rest of the world or the other topics. The third theme is *to see how research helps to the people and society*. Teachers explained this means to see how the research is used to help society and to see why the research and results are important for society. The fourth theme is *to see how the research is used to solve a problem and to apply it*. Teachers stated this means to see whether the research has any applications or global relevance to solve a problem.

The analysis of the pre-interview indicated that for teachers to relate a result to the bigger picture is to explain the effects of the specific research on the overall investigation that has been studied. They also think that it is to find out why the research is important, how the society benefits from the research, and how the research can be applied to a problem in order to find a solution.

Teachers' understandings of relating results to the bigger picture indicated some similarities and differences with the professors' explanations about that practice. Both teachers and professors think that to relate results to the bigger picture is to find out how the research contributes to the research field. Although the professors also made connections with the literature and the results of the research, the teachers did not explain how they are related specifically. In addition to that, teachers and professors pointed out that how the research results can be applied to a situation in order to find a solution that is related to that practice. This suggests that although the teachers' explanations indicated alignment with the professors' explanations, there are differences as well.

Write a scientific report of research. The pre-interview analysis indicated teachers' understandings of writing a scientific report of research have four main themes. The first one is *scientific reports have a format which includes abstract, hypothesis, methods, data, analysis and results,* and most of the teachers' answers focused on that theme. They pointed out that the reports have a specific format and they included specific parts such as problem, introduction, hypothesis, procedure, evidence, data, observations, analysis, literature review, evidence for claims, struggles, references, tables, and figures. The second theme is about the structure again, namely *the format of the scientific reports is standard and structured*. Teachers stated that reports have a specific standard format, it is done in a formal way, and it is written in a technical form. The third theme is *scientific reports inform people about the research*. Teachers described that scientific reports inform the people about what is done, the results of the research, and they inform the people who want to repeat the study. Within the third theme, *reports should have some characteristics*, they explained that reports should be precise, specific, accurate, well written, and easy to understand by other people.

Based on the pre-interview for teachers, scientific reports inform people about the study and should be written in an accurate, well-written, and clear way. They think the components of scientific reports such as problem, hypothesis, procedure, evidence, data, analysis, literature, evidence for claims, struggles, introduction, background, observations, references, tables, and figures are written in a standard and technical format.

The teachers' understandings of scientific reports are more focused on the structure of the writing because they think the reports have a structured and technical format and include specific components. Although the professors explained the structure of the reports, they also made connections between the reports and the literature, but none of the teachers highlighted that the reports move the field forward or inform the literature. Both professors and some teachers stated the importance of the reports in terms of informing the people about the research. This suggests teachers' understandings of the reports are more related to the structure, rather than the purpose and how they are related to the literature.

Think independently about the research area. As reported by the teachers in the pre-interview, their understandings of thinking independently practice can be divided into three themes. The first one is *to come up with a question or problem, to analyze, find results, and* *interpret*. They expressed that to think independently means to come up with all the components of the research yourself such as question, problem, analysis, results, and interpretation. The second theme is *to have your own thoughts*. For teachers this means instead of relying on others' thoughts you should have your own ideas. This requires one to have background information and to be original. The third theme, *to think differently or outside of the box*, means to take blinders off and to see or do the things differently when there is a problem in the research.

The pre interview indicated that teachers believe to think independently means to be able to come up with the components of the research from the identification of the research question or problem to the interpretation of the data without any help, to not rely on the other people's ideas but to have original thoughts about the research based on the background information, and to look at things from a different point of view in order to find solutions for the problems that may occur during the investigation.

The analysis indicated while for professors it means to come up with an idea, take the ownership of the research and to design it primarily by yourself (even if you work with other people or are informed by the literature), for teachers this means to do the research without getting help from other people. Although the research components that were provided by the teachers are limited to research question, hypothesis, data collection, analysis, and interpretation, the professors think it also includes knowledge production and dissemination. The professors stated that thinking independently includes producing new knowledge that is missing in the literature and disseminating it in a proper way, but none of the teachers stated this in their interviews. For professors, critical thinking and making predictions are very important, especially when it is required to make decisions about the research, but the teachers did not make those connections in their explanations. While the teachers stated that it is important not to rely on the other people's ideas, the professors think it is the ability to be able to see the connections between different components in the research by yourself that is important.

As mentioned before, the practices that are presented above were adopted from Kardash (2000), and professors were asked what they mean. Therefore, teachers' understandings of these science practices were compared to the professors' conceptions. In addition, below I present the teachers' understandings of developing and using models, using mathematics and computational thinking, constructing explanations, and engaging in argument from evidence practices. Also, I compared teachers' understandings of these four practices with the explanations in the Framework since in the interview the professors' explanations about the science practices were shorter and included fewer details compared to their explanations about the research skills. For this reason, when the teachers' explanations about those four science practices were examined, the explanations in the Framework were used rather than professors' shorter explanations in order to decide to what extent the teachers understand the science practices.

Develop and use models. The analysis of the pre-interview indicated teachers' understandings of developing and using models produced six themes. The first theme is m*odels are good at representing and simplifying things.* Teachers think models are representations of something you are looking at and are used to simplify the things that are expensive and difficult to reach. The second theme is *they are used for the things that cannot be seen.* They think that models are visuals for the things that cannot be seen, are helpful to understand the things in larger scale, and can be used for abstract concepts that cannot be seen. The third theme is *they could be pictures, animations, visuals, and mathematical representations*. The teachers stated that models are the architecture of the things, which can be animations, drawings, pictures, and simulations. One teacher stated that models can be mathematical. The fourth theme is *they may* *create misconceptions* because they cannot explain the whole thing and are not perfect representations of anything, and they fail to mimic the object at some point. The fifth theme is *they help to understand the concepts and what you mean.* The teachers think that models help to understand what you are trying to explain such as a concept or an idea. The sixth theme is *models represent what is going to happen and going on.* They think that models are used to show what is planning to do; what has happened; and predict what is going to happen in the research.

The analysis indicated that for teachers models are visual tools, such as pictures and animations that are used to represent and simplify the things that are too big or too small and cannot be seen, especially in chemistry. They think that although models help to understand what is going on or going to happen in the research, they do not explain everything about the whole, and therefore may create misconceptions.

The teachers' understandings of models show some similarities and differences with the explanations about the models in the Framework. Teachers' explanations of models are more related to the physical models. For teachers, models are visual tools to represent the things in science. Although the Framework includes the physical models, it also talks about mathematical and conceptual models, but teachers' explanations are more related to the physical models. Teachers think that models help to understand the concepts but cannot explain everything; therefore, they create misconceptions. This is related to the validity of the models. The Framework also addresses the validity of the models because they do not correspond to the entity that they represent. This suggests teachers know that models can help to understand the concepts but their ability to explain all the features of the entity is limited.

Use mathematics and computational thinking. In the pre-interview, nine themes were identified for teachers' understandings of using mathematics and computational thinking practice. Teachers' explanations indicated that they think to use mathematics and computational thinking means *to compare things.* The second theme, *to calculate things*, means being able to do calculations. The third theme is *to find mean, average, or correlation.* The teachers stated that they are used to find average or mean and to think whether there is a mathematical correlation. The fourth theme is *to understand what the data mean.* Some teachers stated that mathematically analyzing something is to explain what the meaning is behind it and to understand what the numbers mean. The fifth theme is *to manipulate and convert the data.* They think this means to convert and organize the data into something that can be mathematically manipulated. The sixth theme, *to solve a problem, to represent and to predict*, relates to the teachers' belief that mathematics can be used to predict what will happen in the future; to solve problems; and to represent the changes in an organism, energy, or frequency. Next, the seventh theme is *to use formulas, graphs, tables, and charts.* The teachers expressed that this means to analyze the data by using formulas, graphs, tables, diagrams, and bar charts in Excel or other programs. The eighth theme is *to find results and conclusions.* They think that it means to analyze the data to get the results and to draw conclusions. Finally, the last theme is *to use statistical analysis*, with some teachers explaining that it goes with the statistical analysis to show a correlation.

The analysis of the pre-interview indicated that for teachers to use mathematics and computational thinking is to find out what the data tells about the research and understand the meaning of that by making comparisons, calculations, and statistical analysis such as averages and correlations; as well as creating visuals such as graphs, tables and charts. They think using mathematics helps to find out the results and conclusions of the research that may help to predict, represent, or solve a problem.

The analysis indicated that teachers' understandings and the explanations in the Framework show some similarities and differences. Both teachers and the Framework explain mathematics and computational thinking in terms of the data analysis and using statistics. In addition, teachers think it is used to represent the data in visual forms. This explanation is also similar to what the Framework says about mathematics and computational thinking. The explanations of the Framework indicate that mathematics and computational thinking is to express the relationships between the variables and it helps to make predictions and solve problems. Although some teachers mentioned those features, most of them were more focused on statistical analysis and visuals, rather than problem solving, predictions, and relationships.

Constructing explanations. According to the teachers' answers in the pre-interview, there are four themes for their understandings of constructing explanations practice. Most of the teachers' understandings focused on the first theme, *to explain why things happened or did not happen in the experiment*. Teachers discussed that this means to be able to explain why things happened with independent thinking, why the effects occur in science, why the phenomena happened, and explain why something happens in the research based on the results. The second theme is *to explain how the results relate to the society*. They think this means to explain how it benefits society; and what the results mean for you, for society, and for the environment as well. The third theme is *to break down what you have done*. They said it is like scaffolding things to get to the bigger concept, trying to build on little by little to make it easy to understand, and to break it down so people can understand what you are doing. For the fourth theme, *to explain the data of the research*, teachers stated that an explanation is a practice which is related to the data interpretation, and it originates from the data collection and analysis. It requires understanding the data and relating it to the hypothesis and explaining the data set in a way to see what it means.

The analysis indicated that, for teachers, to construct explanations is to understand and interpret the data, observations, or models, and relate them to the hypothesis and explain whether or not the research affects the society in a positive way. In addition, they think this is to discuss what and how the things happened in the research, as well as the reasons for the events by breaking them down in order to make them easy to understand by other people.

Teachers' understandings of constructing explanations are more related to how the data and observations are related to the hypothesis and society. Although the Framework states the explanations are related to the data, it also focuses on how they can be used to support the arguments. In addition, while the Framework makes connections between the explanations and scientific theories, teachers' understandings did not show these connections. Teachers also think it is important to discuss the reasons of how things happened in the research. However, in the Framework it is more important to be critical when evaluating the strength and weaknesses of the explanations in order to make strong arguments, but the teachers' understandings did not show those connections.

Engaging in argument from evidence. Based on the analysis of teachers' understandings of engaging in argument from evidence, four themes were identified in the pre-interview. The teachers' answers mostly focused on the first theme *to defend the research.* They think this means to defend the results when you are confident and certain when you have the evidence; to defend the hypothesis with reasonable argument, your point of view, and results; to discuss a point by having something to back you up, such as a validated research which comes from articles and books; and to strongly tell people about the evidence to support what you believe. The second theme is *to discuss the research.* They believe that arguments occur when the results could point in different directions, therefore it means to back it up when someone is going to formulate a different opinion; and to discuss the research if somebody contradicts or has an opposite view of what you said. The third theme is *it is a debate or discourse with experts.* The teachers think this is like a debate and scientific discourse about what you have done; an open dialogue about the research with the experts in the field; and to logically agree or disagree with others who are studying a similar topic. The last theme, *it leads to further questions and new insights, highlights the teachers' belief* that it would help to learn and come up with further questions and a better idea. They stated that through the defense of a position new insights are gained.

The analysis of the pre-interview indicated that, for teachers, to engage in argument from evidence is to have discussions and debates with people, especially professionals in the field; and to defend the research and the findings by using evidence in case somebody has opposite explanations or ideas about the research. Teachers also think that engaging in argument provides opportunities to find out different questions, solutions, and ideas about the research.

The teachers' explanations of engaging in argument from evidence include expressions such as having discussions and debates with the professionals and defending the research or its components. This suggests their explanations are more straightforward, rather than being deep and detailed. The Framework states that this practice is more related to using reasoning and argumentation skills, being critical and identifying weaknesses and strengths in the arguments, and making justified claims. The teachers' understandings did not show those explanations. Their understandings focused more on discussions and debates but not on what should be included in those arguments and how they should be evaluated.

Teachers' Understandings of Science Practices Post Interview

In order to find out how teachers' participation in the RET program affect their understandings of science practices a post-interview was also conducted. The purpose of this interview was to find out teachers' understandings of science practices after they participated in the environmental engineering RET program. Below, I present the analysis of each science practice separately. Each science practice is presented in four paragraphs. In the first paragraph of each science practice, I present the themes that were identified in the interview and what they mean for the teachers; in the second paragraph, I create a description of each theme by putting together the teachers' explanations; the third paragraph compares teachers' pre- and post-interviews; and in the last paragraph, the comparison of teachers' understandings and professors' explanations is presented.

Understand fundamental concepts of research. Four themes were identified for teachers' understandings of fundamental concepts based on the post interview. The theme that teachers' answers focused most on is *fundamental concepts means to understand the basic information and foundation of the subject*. Most of the teachers think that this means to have a basis or foundation to go forth to make connections and solve problems, to have general background knowledge, to have basic knowledge to make informed decisions, to know the subject matter, and to understand the basic ideas and big pictures. Another theme is *to know the new information in the subject*. Teachers expressed this means to be up-to-date on the latest information, research, and knowledge; to read current journals and articles that explain today's research and concerns; and to read, comprehend and engage in conversations about current concepts. The third theme is *to understand fundamental concepts is important for what needs to be done in the research*. Some teachers discussed that to understand the fundamental concepts helps to design what needs to be done, and they are important to design the experiment. The last theme is *to understand the process of research*. Two teachers mentioned this theme, expressing they think that it means to understand fundamental concepts to do research or to understand the process of research.

The post-interview analysis indicated that for most of the teachers to understand fundamental concepts is both to understand the basic ideas and foundation knowledge about the subject matter or the content for making connection and problem solving, and to understand the latest and newest information about the subject matter in order to be able to comprehend and discuss them. In addition, a few teachers think this also means to understand the concepts that are required in designing research.

The comparison of pre- and post-interviews indicated that in both interviews teachers' understandings of fundamental concepts focused more on the concepts of the research or, in other words, the concepts that are related to the subject and content. Although in the pre-interview only one teacher emphasized the concepts of doing research, in the post-interview more teachers stated those concepts. This suggests teachers started to pay attention to the concepts that are related to the process of research. Overall, the analysis suggests that not all, but some, teachers' understandings of fundamental concepts indicated some improvements.

The teachers' post-interview indicated that their understandings of fundamental concepts are more related to the fundamental concepts of research, rather than the fundamental concepts of doing research. In other words, they mostly think the concepts are related to the content or the subject matter which is the foundation of the research, but professors especially stated that fundamental concepts are both related to the research and also doing research. Although a few teachers mentioned the concepts of process of research in the post interview, the explanations they provided are not detailed enough compared to the professors, and they did not make distinctions between fundamental concepts of research and doing research.

Make use of the primary scientific research literature. The teachers' understandings of making use of the primary scientific literature practice were mostly focused on the first theme, *to use the literature as background and fundamental knowledge for your research*. Most of the teachers think that a review of the literature is needed to be done before the research in order to know what you are looking at; it helps to get used to whatever you are going to see in the research and to be current on new ideas to reinforce your fundamental knowledge; to digest the material and use the new information; and to learn the foundation of the concepts used in the research. The second theme is *literature is journals, articles and peer reviewed papers*. They think this is peer reviewed papers published under the scrutiny of the experts, and to read journal articles to understand the concepts related to the research. The third theme is *to see what has been already done*. Some of the teachers mentioned that it means to read research papers to see what others have done and what results were found. The last theme is *to use the literature to go further and reproduce a different way,* means to consider what you can reproduce further after seeing what others have done; to see what you can contribute out after you see the readings; and to think about the research in a different way after being informed about what is going on.

The analysis of the post-interview indicated that teachers feel the primary scientific research serves a baseline and provides background information for researchers about how to do research. They think articles and books are a kind of primary literature which provides information about how previous research has been done and what results are found. In addition, teachers believe literature helps to make contributions after seeing what other people have done related to specific research.

In both pre- and post-interviews the teachers thought that primary literature is publications such as articles and books that show how previous research that is related to the specific research has been done and what kind of findings are present. In the post-interview, the teachers started to add new ideas about making use of primary research literature. In the post interview, they stated that the literature can be used to both reproduce and find a different way for their research. The other difference between pre- and post-interview is while in the pre-interview most of the teachers focused on the journals, articles, and books in their explanations and what has been done before, in the post-interview they tend to explain their ideas about how the literature is used as background knowledge for the research. Overall, the analysis suggests there is some improvement in teachers' understandings of making use of the primary scientific research literature.

The post-interview analysis indicated that although the teachers and professors stated the literature serves as a baseline in order to see what has been done before and what findings are obtained, there are additional ideas the professors pointed out which none of the teachers explained. For instance, the professors made the connections between the literature and finding the knowledge gap and constructing research questions, learning the norms and standard measurements, but the teachers did not state those explanations. This suggests that although teachers mention the literature is a foundation for the research, they do not provide the information about how they can use it for their research like professors.

Identify a specific question for investigation. Teachers' understandings of identifying a specific question for investigation practice in the post-interview produced six themes. First one is *it means to find a specific issue, problem or need*. Teachers think that to identify a question is to figure out a problem in order to explain or solve it and to identify a need or aspect within overarching research that needs to be worked on. The second theme is *to focus on and narrow down the research*. The teachers expressed this is like a focus on the research to find a specific knowledge, to choose one specific question to narrow the research by developing a hypothesis, and to narrow down the research to one question. The third theme, *the question related to the purpose of the research*, relates to the teachers' concept of what it is what you are trying to figure out with your research. One teacher mentioned this means to create a question or a hypothesis (basically your objective for doing research), while the other said it is to know why you are researching the purpose, goals, and question. The fourth theme is *to identify something to test it*. This theme was derived by two teachers who think this means to identify something to see if there is a statistical significance related to one specific variable. The fifth theme is *the question should be specific and testable*. Some teachers think that the question should be specific that can be tested, and the question should be testable someway through the experimental-control group scenario. The last theme is *to find a question during the observations*. The teachers' answers indicated this means to isolate a testable question from observations.

The analysis indicated that for most of the teachers to identify a specific question for investigation is to find out a problem situation or an issue in order to narrow down the focus of the research. In addition, a few teachers think that the research question should be related to the objective or the goal of the research, and it should be tested in order to see whether there is a significant difference on a specific variable.

The analysis indicated that in both pre- and post-interviews the teachers' understandings of identifying a specific question for investigation is related to finding a problem or an issue and narrowing down the research to investigate. Although in the pre-interview the teachers stated that the question should benefit society, these explanations were not found in the post-interview. In both interviews, a few teachers stated that the research question should be testable. Although this explanation is good, the number of teachers who talked about this is still low. In the post-interview, some teachers emphasized that the research question should be related to the purpose of the research, but that is not identified in the pre-interview. This suggests some teachers started to make connections between the goal of the research and the research question. Overall, the analysis suggests that teachers' understandings of identifying a specific question for investigation did not improve in the program, but a few teachers' understandings indicates some improvements.

The teachers' understandings of identifying a specific question for investigation indicated that most of the teachers think a research question is related to finding a problem or an issue, but they do not explain how they come up with those problems. On the other hand, the professors stated that the research question is identified based on the knowledge gap in the literature and the current state of knowledge, but none of the teachers made a connection between the research question and the literature. It is good that teachers emphasized that the research question should be related to the goal of the study because professors also stated that connection, but this connection is only made by a few teachers.

Formulate a research hypothesis based on a specific question. The teachers' understandings of formulating a research hypothesis based on a specific question practice generated five themes in the post-interview. The theme that was found in most of the teachers' answers is *hypothesis is the possible answer to the research question and it is what you think is going to happen or a prediction*. This theme includes the answers such as: it is basically what you think that you want to know, the possible answer to the research question, and your guess what is going to happen. It also means to create a probable answer to the research question, to decide how you think is going to work out in the experiment, to make a prediction that can be proved or disproved, and to pinpoint exactly what you are looking for in the project. Another theme found in the post interview is *background information and literature informs the research hypothesis*. Teachers mentioned that the hypothesis is formed based on the literature and background knowledge, and the articles that are read. The next theme is *the format of the hypothesis is if-then statement*. Teachers think that the format of the hypothesis has dependent and independent variables. They also think that inductive reasoning from previous data is used to develop the form of if-then statement. The last two themes are opposite of each other. While some teachers think that *the hypothesis is a guess,* some think that *it is not a guess*. For example, one teacher explained it as, “It is to use evidence from experiments to come up with a possible guess to what would happen,” but the other teacher said, “It wouldn't be just a random guess, it would be you are using evidence or you are using logic from past experiments or what you know already to make an informed.” One teacher mentioned that, “It is not an educated guess because it is more than that.”

The post-interview analysis indicated that teachers believe a research hypothesis is a kind of prediction about what is going to happen in the research; therefore, it is the possible answer to the research question and it is determined based on the literature. They also think that the hypothesis is an if-then statement that shows the relationship between dependent and independent variables. In addition, although some teachers think that it is a guess about what will happen in the research, some of them do not agree with that.

In both pre- and post-interviews, the teachers’ understandings included the structure of the hypothesis because they think it is an if-then statement. In addition, in both interviews the teachers think that a hypothesis is the possible answer to the research question and a prediction that shows what is going to happen in the research. The interviews indicated that the hypothesis is identified based on the literature. This explanation is good because the professors agree, but the number of teachers who mentioned this is still low. In the post-interview, few teachers stated that hypothesis means to come up with a guess, but that is not found in the pre-interview. Overall, the analysis suggests that the teachers' understandings of formulating a research hypothesis did not improve in the program.

In general, the teachers make the connection between the research question and the hypothesis because they think it is a prediction of the answer of the question. Professors also think it is the initial understanding of the research question because they think it is what you expect to find in the research, and it is the assumption or the possible answer to the research question. Although, from this point of view the teachers' understanding of the question is aligned with the professors, some of the teachers were more focused on the structure of the hypothesis as an if-then statement. The professors' explanations are more focused on what the hypothesis is and how it is related to the research, but some of teachers focused more on the structure of the hypothesis. In addition, a few teachers think the hypothesis is a guess, but none of the professors used that expression in their explanations.

Design an experiment or theoretical test of the hypothesis. Based on the analysis of the post-interview four themes were identified for teachers' understandings of design an experiment practice. The first theme is to *design an experiment means to find a way to test the hypothesis.* Here, teachers think that design an experiment means to develop ways to actually test the hypothesis, to look at the most viable ways to investigate the hypothesis, and to set up an experiment to see whether your initial thinking is going to happen. The second theme is *designing an experiment needs to have controls and variables*. They think that designing an experiment includes identifying different variables that affect the process and the controls, and it needs to have manipulated variables. The third theme is to *design experiment is to determine the steps to follow for the research*. In this theme, the teachers pointed out that it means to design the experiment with dependent and independent variables to test the hypothesis. The last theme found in teachers' post-interviews is *design an experiment means to find a relationship or statistical significance between the variables*. They think that it is to define a process by which one variable is being tested to find a relationship, to see whether there is a statistical significance, and to test the hypothesis to see if there is a cause and relationship.

The analysis of the post-interview indicated that teachers feel to design an experiment is to develop a way or a process to follow by determining the controls and variables in order to test the hypothesis and to find whether or not there is a relationship or significant difference between the variables.

The teachers' understandings of designing an experiment indicated similarities in both pre- and post-interviews. For example, in both interviews they think to design an experiment means to find a way or process to follow during the research. In both interviews, they think that the designing of an experiment includes identifying the variables and controls in order to answer the question or to see whether the hypothesis is supported or not. The only difference between the two interviews is while in the post-interview the teachers think design an experiment is related to finding whether there is a significant difference or relationship between the variables, in the pre-interview they did not talk about that explanation. Overall, the analysis suggests that teachers' understandings of designing an experiment did not improve in the program, but a few teachers' understandings indicated some differences.

Based on the post-interview analysis it can be said that both teachers and professors described the design of an experiment as a way or a process to follow and to answer the research question or to see whether the hypothesis is supported. In addition, the teachers and professors think the design of the research includes determining the controls and the variables that will be used in the study. Although the professors emphasized that the research should not depend too much on the hypotheses (or the researchers should not try to prove the hypothesis because this may cause to interpret the results in a wrong way), none of the teachers made those connections. In addition, the professors think that the researchers should be ready to modify the hypothesis, but the teachers did not state those explanations about the research design.

Understand the importance of control. Seven themes were identified for teachers' understandings of the importance of control in the post interview. The first one is *the baseline and foundation*. Teachers think that control is a baseline to see how much variables are affected and it is a basis to go off. The second theme is *it helps to validate and to check the results*. Teachers expressed that it helps to make sure the results are not naturally occurring, it helps to say whether the results are accurate or not, and it helps to validate the research. The third theme, *control stays constant,* shows that teachers mentioned control is a static process that runs simultaneously in the experiment and it is something that remains constant. The fourth theme *is it helps to compare*. Teachers explained that it helps to actually compare what you are seeing. Another theme is *it helps to see the effect, difference and the change*. They think that it allows one to see how varying one element has an effect, to see the variance of one variable, and to see the variations in a more accurate way as well. The sixth theme is the *controlled variable*. While some teachers talked about the control group, the other teachers mentioned the controlled variable. They think that this means to keep every parameter or factor controlled. And last theme is *control is the blank, neutral, or null set*. They think control is basically the null set that shows how things happen in nature, it is a blank that helps to know exactly what is going on in the experiments, and it is a neutral factor that has no variables acting up on it.

The analysis of the post-interview indicates that, for teachers, control serves as a baseline in order to make comparisons and to see whether there is a difference or change on one of the variables in the research. In addition, they think control is a null set or blank that stays constant during the experiment, which helps to check whether the results are valid or not. The teachers talk about either the controlled variable or control group, but none of the teachers explained them separately or provided information about the differences between them.

In the pre- and post-interviews most of the teachers' understandings are related to the idea that controls remain the same in the experiment. In both interviews, they thought that control is the baseline and foundation which stays same or constant in the research; therefore, it helps to compare and see the effects and differences in the study. In both pre- and post-interviews, the teachers either explained the controlled variable or control group, but they did not specifically mention they are different or what the differences are. Only seen in the pre-interview, some teachers thought control makes the data more reliable and minimizes the different factors. This idea was not identified in the post-interview. Instead, only in the post-interview, some teachers thought control is the blank, neutral, or null set, and it helps to validate the research. Overall, the analysis suggests that the teachers' understandings of the importance of controls did not improve in the program.

One of the obvious differences between the teachers' understandings of controls and the professors' explanations is the difference between the controlled variable and control. It is good to see that the teachers think control serves as a baseline and helps to make comparisons because the professors also stated that in their explanations. Although this part is similar to the professors, the teachers did not explain controlled variable and control group separately and how they are different. The professors think that control is like a baseline to compare and come up with the conclusion. A controlled variable is the variable that stays constant in the experiment. For instance, if the temperature is constant during the experiment it means the controlled variable is temperature, but it is not a control group.

Make observations and collect data. Based on the post-interview, the teachers' understandings of collecting data practice have seven themes. The first theme is *to gather qualitative and* quantitative information. The teachers stated that qualitative and quantitative observations should be taken for data analysis. In addition, they think it means to record the qualitative and quantitative information and to use scientific methods to gather qualitative and quantitative data to see whether the hypothesis is correct. One teacher said observation could be subjective or numbers. The second theme is *to take measurements and recording the observations*. They stated that data collection is about taking measurements and counting, recording the data is important for data collection, and it means to record what you are observing to see what is happening in the research. In the third theme, *using the senses to gather data*, they think that making observations means to use the senses to gather information and to purely use what your senses perceive. The fourth theme is *observation provides different information.* Here, the teachers think that it is more about the visual properties of the experiment, making observations help to see whether any variables overlooked, and making observations is more than what you are looking at. The fifth theme is *data collection allows checking what is done,* with one teacher stating it helps to check whether there is a problem in the research.

The teachers think that to make observations and collect data is to take measurements and recording the observations in order to gather qualitative and quantitative information for the purpose of seeing whether the hypothesis is supported by the data. In addition, it is using senses such as seeing, smelling, and hearing to gather information for data collection. Only one of the teachers stated that making observation helps to check what is going on during the research.

The analysis indicated that in both pre- and post-interviews teachers think that to make observations and collect data is to gather qualitative and quantitative information by taking measurements and recording them or using senses to see what is happening in the research to find out whether the hypothesis is correct. There are a few differences between the pre- and post-interviews. For example, only in the pre-interview one teacher stated that observations and data collection should not be biased, and one teacher stated that observation helps to check what is going on in the research explanations only in the post interview. Other than that the other expressions did not show much difference. Overall, the analysis suggests that the teachers' understandings of making observations and collecting data did not improve in the program, but one teachers' understanding indicated some improvement.

Although a few teachers mentioned making observations is good to check what is going on in the research, most of the teachers' understandings indicated that they do not make a clear distinction between making observations and collecting data. In contrast, the professors emphasized there are differences between making observations and collecting data, such as observation is more related to quality control of the experiment and seeing whether there is a problem in the experiment and trying to solve the problems, whereas data collection is more related to gathering quantitative and qualitative information. The teachers also think that using the senses is part of the data collection, but the professors did not state anything about senses in their explanations.

Analyze numerical data. The teachers' post interview analysis indicated that their understandings of analyzing numerical data have five major themes. The first theme is *to put the data into graphs, charts, and spreadsheets*. Teachers explained that to analyze numerical data means to use a spreadsheet in Excel and create graphs, scatter plots, and charts. The second theme is *to find a trend or pattern in the data*. Some of the teachers' answers indicated that they think it means to extrapolate the information to show the various trends and to find the patterns in the data. The third theme is *to use statistics and to find correlations and comparisons*. They think that data analysis involves finding calculations, comparisons, correlations, and relationships in the data. The fourth theme is *to see the results and use them for conclusions and to make decisions*. They think data analysis is done to find the results and conclusions. The fifth theme is *to find what the data mean and make sense*, with the teachers showing they think it is to find what the numbers mean and to look at the data and make sense of it.

The analysis of the post-interview indicates that according to the teachers, data analysis is to use statistics, calculations, and comparisons or creating visuals such as graphs, charts, or tables to identify whether there is a trend, pattern, relationship, or correlation in the data. They think that data analysis gives information about what the data means and helps to make conclusions and decisions.

The analysis of pre- and post-interviews indicated that teachers' understandings in the pre-interview mostly stayed same in the post interview. For example, in both pre- and post-interviews they think that data analysis is a way to see what the data means and to find out whether there is a trend or pattern, correlation, and comparison by using statistics and creating visuals. Only seen in the pre-interview, a few teachers stated that finding the reasons why the data showed or not showed the expected measurements is related to the data analysis. Also, only in the post-interview did some teachers think that data analysis helps to find the results and use them to make conclusions and in decision making. Other than these differences, teachers' understandings did not demonstrate much difference. Overall, the analysis suggests that the teachers' understandings of analyzing data did not improve in the program, but a few teachers' understanding started to indicate some improvements.

Both teachers and professors emphasized that statistics is used in order to determine whether there is a trend or pattern in the data. Although the teachers mentioned that data analysis includes comparisons, they did not explain how they use comparisons to analyze the data. For instance, the professors stated that the comparison of the treatment and control samples is used to find if there is a statistical significance or not. Teachers also think that to analyze numerical data helps to construct conclusions. In addition, the professors stated that data analysis is to find the power of the replicates and statistical power, but none of the teachers' explanations included those expressions. Although the teachers talk about statistics, the level of the terms they use is not equal with the professors.

Interpret the data by relating results to the original hypothesis. In the post-interview, the theme that was focused on by most teachers was *interpreting data means to determine whether the data and results support the hypothesis*. Most of the teachers think this means to analyze the data, and go back and see if the hypothesis is right or wrong; to compare the data with the hypothesis to see if it is accurate; to make comparisons to see if the hypothesis is correct; and to see if the data is in line with the hypothesis or conflicting with it. The next theme that is identified in the post-interview is *interpretation means to see what is coming out of the* *data*. Teachers think that it is to identify any statistical significance in the data, to look at the trends in the data and graphs, to say what implication you found in the conclusion, and to see what the data mean. And last theme is *if the hypothesis is wrong to go further and change*. Teachers think that it means to determine whether you need to change the hypothesis or method and to explain why the data conflicts with the hypothesis.

Based on the post-interview analysis for teachers, data interpretation is to determine what the data mean and to see whether there is a trend or statistical difference in the data. In addition, they think that it is to find out whether the data or the results support the hypothesis. If the data do not support the hypothesis, it is required to make necessary changes in the hypothesis or in the design of the research.

The analysis indicated that although teachers' understandings of interpreting data by relating results to the original hypothesis has a few differences in the post-interview, most of the ideas in the pre-interview remained same. In both pre- and post-interviews, teachers think that to interpret data is to find out what the data mean, whether the data and results support the hypothesis, and to make the changes to the hypothesis if it is not supported by the data. The biggest difference in the pre- and post-interviews is the number of the teachers who stated data analysis means to determine whether the data and results support the hypothesis. Although this idea is provided by some teachers in the pre-interview, more teachers focused on it in the post-interview. The other important finding is most of the teachers confuse the data analysis and interpretation because they provided similar explanations for these two science practices. Overall, the analysis suggests that the teachers' understandings of interpreting data did not improve in the program, but a few teachers' understanding started to indicate some improvements.

The interviews indicated that teachers' understandings of data analysis and their understandings of data interpretation is similar because for data analysis and interpretation they think both are to find out a trend in the data or a statistical difference in the data. This suggests some teachers still confuse the difference between data analysis and interpretation. Although their thinking about finding out whether the data support the hypothesis and making changes to the hypothesis or in the design is aligned with what professors stated about data interpretation, some of the teachers still are not clear about the differences between data analysis and interpretation.

Reformulate the original hypothesis. Two themes were identified based on the teachers' answers in the post-interview. The first is the major theme because most of the teachers' understandings focused on that theme, *to change the hypothesis when the data and results don't support it*. Most of the teachers think this practice means to change the hypothesis based on the experiments, measurements, and observations; to compare the hypothesis with the results to see whether it is supported or not; to update the hypothesis based on the new knowledge; and to restate the hypothesis if the results don't agree with it. The second theme is *to make more experiments and testing*. Some teachers specifically mentioned that it is to make changes in the experiments, re-plan the experiments, and to run different trials with a modified hypothesis based on the limitations.

The interview analysis indicated that for teachers to reformulate the original hypothesis means to modify the hypothesis or find a new one if the data, observations, and measurements do not match with it. In addition to changing the hypothesis, they also think that the modifications in the experiments and running different trials are sometimes required if the data do not support the hypothesis.

The pre- and post-interview analysis indicated that there is not much difference between teachers' explanations in the pre- and post-interviews. In both interviews, they expressed that to reformulate the original hypothesis is to make changes to the hypothesis if the data and results don't support it. That is the most focused answer of the teachers in both pre- and post-interviews, but the number of teachers who stated this increased in the post-interview. This suggests that the idea of "changing the hypothesis or the experimentation if data and results do not match with the hypothesis" was more focused on by the teachers. Overall, the analysis suggests that the teachers' understandings of reformulating the original hypothesis did not improve in the program.

Teachers' understandings of data interpretation demonstrated some similarities with the professors' explanations. For instance, both teachers and professors stated that reformulating the original hypothesis means to determine whether the data and results support the hypothesis and to change it if it does not match with the data. In addition, both teachers and professors stated that reformulation of the hypothesis may require running different trials. The professors pointed out that the researchers and the research design should be flexible to make changes, but the role of the researcher and the flexibility of the research were not mentioned by the teachers.

Orally communicate the results of research. In the post-interview, six themes were identified for teachers' understandings of orally communicating the results of research. Most of the answers were focused on the first theme, *orally communicate means to talk about what you found, results, and what you did*. Teachers think that it means to be able to speak about the research, to communicate what you did during the research, to discuss the project, to express what you saw and found, and to talk about to other people about what you did and why things happened in the research. The second theme is *to speak in a manner that people can understand* *what you are saying*. The teachers feel this means the communication should be understandable by other people. They think this it is to communicate the research, results, and data based on the audience; and to talk reliably, well, and in a manner that helps to people easily understand. The next theme is *to give a presentation in a scientific community*. The teachers think that to present the research in a conference means oral communication. Another theme is *it helps to make sure it is a valid study*, where two teachers mentioned that oral communication helps to validate the research in the scientific community. Two teachers also mentioned that *it means to communicate through journals*. They think that to communicate to society and the scientific community through research journals or publications and to disseminate the material in a professional journal is oral communication. And finally, one teacher said it means *to answer the questions about the research*.

The analysis of the post-interview suggests that teachers state to orally communicate the results of research is to speak about the research components such as the findings, results, and conclusions verbally and answering the questions by giving a presentation in a scientific community, such as in a conference or by making a publication. They think that the communication should be done in a way that other people can understand it. In addition, a few teachers think the discussion of the research with other people helps to validate the research because it helps to see the problems that might emerge during the study.

The analysis indicated that although the explanations the teachers made in the pre-interview related to oral communication, there are a few differences that are found in the post-interview. In pre- and post-interviews, the teachers thought that oral communication is a way to speak about and defend the research and findings in a scientific community, such as conferences and answer questions from the audience. In the post-interview, some of the teachers stated that the communication should be done in a way so other people can understand the research. Although they stated in the pre- and post-interviews that oral communication helps to see the problems in the research, in the post-interview they also pointed out that oral communication allows one to validate the research. Overall, the analysis suggests that teachers' understandings of designing an experiment did not improve in the program, but a few teachers' understandings indicated some differences.

Both the teachers' and professors' explanations indicated that orally communicating the results of the research can be done in a formal way, such as a conference. In addition, the professors stated the informal ways of communicating the results such as lab and research group meetings, but the teachers did not talk about those. A few teachers think that oral communication helps to see the problems in the research. This expression is good because the professors also emphasized the same point, and they think that oral communication helps to see possible solutions for the problems as well.

Relating results to the bigger picture. The analysis of the post-interview indicated that there are six themes for teachers' understandings of relating results to the bigger picture practice. The first theme is *how the research contributes to the overall research*. They think that the research is an important component of the overall research because the findings are used for recommendations. In the second theme, *how the research relates globally*, they explained that it means to look at how the research relates globally and to the things outside of the research. The third theme is *to see how the research helps to the society and people*. Here they discussed that the bigger picture is everything else that would help people, and relating results to the bigger picture means to look at what relevance the research has for an application in society. The fourth theme is *to see how the research is used to solve a problem and to apply*. Teachers explained that it is important to know how the research findings can be used to solve problems and to apply them in order to come up with a better way for the environment. The fifth theme is *the research is a smaller part or model of the bigger picture*. They think that this means to apply a small model to a bigger global picture to understand what is going on. And last theme is *the bigger picture is like a puzzle that you can connect to*. They mentioned that the bigger picture is kind of a puzzle that you try to put together and connect the pieces of it.

The post-interview analysis suggests that, for teachers, relating results to the bigger picture is to find out the contribution of the specific research to the overall study and to determine the relationships between the research and its global effects. The teachers think this is to see how society benefits from the research findings and how the results can be applied to solve a problem. In addition, teachers said research is a small part of the overall study and the big picture is like a puzzle that connects the results of the other, smaller research studies.

The analysis indicated that although the teachers made connections between the contributions of the research to the overall study, the professors specifically made the connections between the research and the field or literature. Both the teachers and professors stated that to relate results to the bigger picture means to explain the research findings and how they can be applied to solve a problem. Although the teachers think the bigger picture is like big puzzle and the specific research is kind of a part of the puzzle, the professors did not provide that kind of explanation for the big picture. Overall, the analysis suggests that the teachers' understandings of relating results to the bigger picture did not improve in the program.

In both pre- and post-interviews, the teachers made connections between research findings and how they are related to the overall investigation. Although in the pre-interview one teacher explained the relationship between the effects of the specific research on the research field, none of the teachers stated that in the post-interview. They also explained the research findings and its effects on society and how they can be used to solve a problem in both the pre- and post-interviews. In addition, in the post-interview, they explained that the big picture is like a puzzle and the research is one of its parts. The teachers did not state that idea in the pre-interview.

Write a scientific report of research. The teachers' understandings of writing a scientific report of the research produced five themes. Most of the teachers' answers focused more on the theme that is related to the format and structure of the reports. This theme is *it has a format that includes abstract, methods, data, analysis, and results.* They think that a report includes an abstract, introduction, background, methods, facilities, conclusions, observations, results, materials, analysis, and purpose. They also think that it means to write what you did, your reflection, evidence, and what happened in the research. The next theme *is reports inform the people about the research and it should be based on the audience.* Teachers think that it means to put everything together in a way that is easy to communicate so people can understand the research. The third theme is *to create a journal article and to publish the research*. Teachers' answers indicated that they think it means to create a journal article that shows what is tested, what is changed, the variables, and controls. The next theme is *its format is structured*. Two teachers mentioned that the structure is pretty much fixed, and if you know the structure you can easily understand what is going on by looking the specific parts.

The teachers' post-interview analysis indicated that scientific reports are written in a specific and structured format that has the components of the research such as an abstract, introduction, background, methods, facilities, conclusions, observations, results, materials, analysis, and purpose. They think that the reports can be journal articles and publications that are written to inform people about what is done and found in the research; therefore, it should be written in a clear way in order to help the readers to understand it.

In both pre- and post-interviews teachers' explanations about writing a scientific research report focused on its structure and components that should be included in the report. They think the components of the reports are written in a structured and technical format like journal articles. In addition, in both pre- and post-interviews they stated the reports are written in order to inform people about the research and what findings are obtained from the study. Therefore, it should be written in a clear way. In the post-interview, the teachers especially stated that to create a journal article and publish the research is a kind of scientific report. In the post-interview, one teacher also stated that the reports should be based on the audience so those people can understand the study clearly. Overall, the analysis suggests that the teachers' understandings of writing a scientific report of research did not improve in the program.

The teachers' understandings of writing a scientific report of research was more focused on the structure of the report and which components should be included. Although the professors also stated and listed the components of the reports, they explained the purpose of the reports is to move the field forward or to inform the literature. A few teachers mentioned that the scientific reports inform the people, but they did not make connections with the literature.

Think independently about the research area. In the post-interview, five themes were identified for teachers' understandings of thinking independently about research area. The first one is *think independently means to have your own thoughts and ideas*. The teachers think that this means to formulate your own ideas for your research, to have your own thoughts on your experiments, to not just relying on what other people have said, and to use other's knowledge and data to formulate your own ideas. The second theme is *to come up with a question, hypothesis,* *and plan without getting help from other people*. Teachers think that to think independently requires coming up with the research question and planning the research to find the answers without other people's help. The third theme is *to think differently and with new eyes*. Some teachers mentioned this is to have new eyes from the outside of the specialty and to look with new eyes at an old problem and see the things in a different way. One teacher said that it is important because different perspectives are needed for the advancement of science. The fourth theme that was identified in the interview is *to have a good understanding of your research area*. Here, teachers think it means to be confident in your ability to know what you are doing in your content and to have a firm understanding of a certain topic. And the last theme is *to solve a problem*. Two teachers explained that it means to have the ability to solve a problem if something doesn't work in the research and to make a change to solve a problem after having information about the topic.

The analysis of the post-interview indicated that for teachers to think independently means to be able to come up with the components of the research from the identification of the research question or problem to the interpretation of the data and conclusion without getting help, to formulate and use your original thoughts about the research and to not rely on only the other people's ideas, to look at the things from different perspectives especially when there is a problem situation or when reading a paper, to understand the research field firmly in order to be confident about the content and what you are doing in the research, and to be able to solve the problems by making necessary changes in the investigation.

In both pre- and post-interviews the teachers believe that to think independently means to come up with the components of the research without getting help from other people. Although in the pre-interview teachers only mentioned a few components such as to come up with a question or hypothesis, in the post-interview they also added the interpretation, results, and analysis. In addition, in both interviews they stated that to think differently is a characteristic of thinking independently because it helps to see the things with another point of view. In the post-interview, the teachers also pointed out that the researcher needs have a good understanding of the research area to be able to solve problems. Overall, the analysis suggests that the teachers' understandings of thinking independently did not improve in the program.

The analysis indicates that for both teachers and professors to think independently is to come up with the components of the research. For professors, thinking independently includes the ability to disseminate the information about the research, such as writing an article and producing new knowledge and making contributions, but none of the teachers stated anything about dissemination of the research. The teachers think that to think independently is related to not to relying on other people, but for professors it is not related to relying or not; it is more about being critical when doing the research or when reading a paper. For both teachers and professors, thinking independently is important to solve the problems that may emerge during the research. The professors made connections between thinking independently and being able to make predictions about the research results, but the teachers did not state those connections.

As it is stated before, the practices that are presented above were adopted from Kardash (2000) and professors were asked what they mean. Therefore, the teachers' understandings of these science practices in the post-interview were compared to the professors' conceptions. In addition, below I present teachers' understandings of developing and using models, using mathematics and computational thinking, constructing explanations, and engaging in argument from evidence practices. Also, I compared teachers' understandings of these four practices with the explanations in the Framework since in the interview the professors' explanations about the science practices were shorter and included fewer details compared to their explanations about the research skills. Because of this reason, when the teachers' explanations about those four science practices were examined, the explanations in the Framework were used rather than professors' shorter explanations in order to decide to what extent the teachers understand the science practices.

Develop and use models. In the post-interview, eight themes were identified for teachers' understandings of developing and using models. The first theme is *models help to understand the concepts, systems and what you mean*. Teachers think that they make the concepts more easily understandable, they give a good basis of general understanding of something, they help to understand of mechanisms or processes in natural system, and they help people to understand what you are talking about by using graphs and charts. The second theme is *they simplify and represent things*. For teachers, models are simplified versions of something, they are used when the real thing is too expensive and unpractical to use, and they simulate the conditions of the actual design. The third theme is *models represent what is going on*. They stated that models give a better representation of what happened in the research and give a concrete basis of what is actually happening. In the fourth theme, *models are used for things that cannot be seen,* they think that models provide ways to make abstract concepts more concrete because they are visuals that help people to understand too small or too big things. The next theme is m*odels are visual representations, animations or mathematical models*. Teachers think that models are visual representations of the concepts such as illustrations or computer animations. Three teachers emphasized that mathematical models help to explain what is going on in the research. The next theme is *models don't explain everything*. One teacher mentioned that models are not able to explain every feature of the concept. And the last theme is *models* *allow predicting*. Two teachers stated that models allow predicting and to communicate to other people about how you can best predict the results of a process.

The analysis of the post-interview indicated that, for teachers, models are visuals such as animations or pictures which help to represent and simplify concepts and systems, especially those that are too big or small things that cannot be seen. They also think that models help to explain what is going on during the research and predict what will happen at the end of the process. Although most of the teachers think that models help to understand the concepts, one of them thinks that models cannot explain everything because they are not perfect representations.

The analysis indicated that teachers' explanations in the pre-interview stayed same in the post-interview about the models. In both pre- and post-interviews, teachers stated models simplify things that cannot be seen because they are visual representations; although they help to understand the concepts and systems, they cannot not explain everything and therefore they may create misconceptions. This suggests that in both the pre- and post-interviews, teachers' understandings of models are more focused on physical models rather than conceptual and mathematical models. Although three teachers mentioned mathematical models, the other teachers did not talk about them. Overall, the analysis suggests that most of the teachers' understandings of developing and using models did not improve in the program, but three teachers mentioned mathematical models; therefore, their understanding changed in the program.

The teachers' explanations about models suggest that their understandings are more related to physical models because they think models are visuals such as animations and pictures. Physical models are included in the Framework (NRC, 2012), but in addition to that the Framework also explains mental and conceptual models. The analysis indicated that none of the teachers spoke about those models. Both teachers and the Framework stated that models help to predict what will happen in the research and help to understand the concepts. Although the Framework also emphasizes models are good tools to understand the concepts, it also points out the validity of the models. Some of the teachers think that models may create misconceptions because they are not perfect representations. This explanation is related to the validity of the models. This suggests some teachers are aware of the validity, but it is expected that the other teachers also have that understanding. The Framework explains models helps to improve scientific reasoning, but none of the teachers made that connection.

Use mathematics and computational thinking. Seven themes were identified for teachers' understandings of using mathematics and computational thinking in the post-interview. The first theme, which the teachers' answers focused more on, is *using mathematics means to use a formula, equation, graphs and model*. For teachers it means to use a mathematical model to describe what is happening in the experiment; to make graphs to come up with the answer; to use a formula; and to use equations to measure frequencies and changes. The second theme is *to understand what the data mean*. Teachers think that it means to know what all the numbers mean and to make sense of the data. The third theme is *to manipulate, correct or switch the data*. It means to correct the data to understand it in a way you are looking for, to manipulate the numbers or convert them, and to switch the data into a more comprehensible format. The fourth theme is *to calculate data*. Some teachers only said it is to calculate data or to calculate quantitative data. One teacher mentioned that it allows one to mathematically compute the results. The fifth theme is *to find an average or standard deviation.* This theme is related to the fourth theme but is more specific. Some teachers said it means to find the average and standard deviation of the data. The sixth theme is *to compare the data*. One teacher mentioned that it means to compare the data. And seventh theme is *it is used to solve issues,* with one teacher stating that mathematics is used to solve issues.

The teachers' post-interview analysis suggests that they believe mathematics and computational thinking is used to explain what is happening or what will happen in the research; to use statistical analysis and make comparisons and calculations, such as averages and standard deviations; to create some visuals, such as graphs and models; and to use mathematical expressions, such as equations and formulas. Also, they think that mathematics is used to manipulate or switch the data in order to explain it in a more comprehensible way and to solve problems that are related to the research.

The analysis indicated that in the both pre- and post-interviews, for teachers, to use mathematics and computational thinking did not show much difference. Their explanations were focused on statistical analysis, to represent the data in visual forms, to understand the data, and using formulas and equations. Therefore, this suggests teachers made the connections between using mathematics and data analysis in their explanations in both the pre- and post- interviews. Overall, the analysis suggests that the teachers' understandings of using mathematics and computational thinking did not improve in the program.

Both teachers and the Framework state that mathematics is used to analyze data and create visuals to represent the data. The Framework points out that mathematics is used to find out the relationships between the variables and to express them in mathematical forms. The teachers did not express this in the same way, but they mentioned mathematics is used to create equations and formulas and to solve problems that are related to the research.

Constructing explanations. Based on the teachers' post-interview three themes were identified about their understandings of constructing explanations. The first theme is explanations means *explaining what, why, and how things happened in the research*. They think that to explain how things worked, what you are seeing in the experiments, what you obtained from the research and what is going on, why the data and observations are important, why things worked or happened, and to look at the data and explain why things happened are related activities about this practice. The second theme is *to make an assumption, conclusion or correlation*. They discussed that it means to generate cause-effect correlations and to make an assumption or conclusion based on the data. The third theme i*s to explain how the research relates to other areas of research*. They think that it means to construct explanations for colleagues to understand the relevance of the research.

The analysis of the post-interview suggests that for teachers constructing explanations is to explain what results are found in the research, to provide information about the reasons for why the things worked or did not work, to explain the relationships between the research, and its effects and other fields. In addition, making conclusions and assumptions based on the findings are related to that practice.

In the pre-interview, teachers' explanations were more focused on explaining what is done in the research and why they were done in specific ways by using evidence to explain what the data means and what is coming out of the data and how it is related to the hypothesis, and how the research affects society. In the post-interview, teachers' answers were more focused on making assumptions, conclusions based on the data and findings, and how the research affects the other kinds of research studies. This suggests that while in the pre-interview teachers' answers were more related to the explanations about data, hypothesis, and the research process, in the post interview their explanations were more related to findings, conclusions, and their effects. Overall, the analysis suggests that the teachers' understandings of constructing explanations did not improve in the program, but a few teachers' understanding started to indicate some improvements.

Teachers' understandings of constructing explanations indicated differences with the Framework. The Framework explains that practice such as making connections to scientific theories, models and representations, but the teachers did not point out those connections. Although the teachers and Framework state that the explanations are constructed based on the results, the teachers do not relate it to support or not support arguments as it is explained in the Framework. In addition, based on the Framework making evaluations and critiques of people's explanations are important to construct meaningful arguments, but the teachers did not state anything about that in their descriptions.

Engaging in argument from evidence. According to the teachers' answers in the post-interview four themes were identified for engaging in argument from evidence practice. The first theme is *to defend the research and the data*. They think that this practice is defending all the components of the research, including what is obtained from the research, the credibility of the data, conclusions, and what you did. They also think it means to prove what you observed, the data, and your point of view. The second theme is *to discuss the research if somebody contradicts*. Teachers stated that it means to argue the research outcomes when they are in contradiction to other research, to argue for against something based on the knowledge base, and to back up the research if someone comes with a reasonable why. The third theme is *it is a good way to check*, they think it is not only sharing the results and arguments, it is also a good way to check whether the research has problems.

The post-interview analysis indicated that, for teachers, to engage in argument from evidence is to have discussions with the people who provide contradicted arguments and to defend and prove the research and all its components such as data, conclusions, validity, and reliability. Teachers think that engaging in arguments with different people helps to check whether the research process is completed in the right way.

The teachers' explanations indicate that in both pre- and post-interviews they thought engaging in argument from evidence is to defend the research and its components such as data, results, and findings; and to discuss and support the research if somebody contradicts it. In addition, they stated that to engage in argument helps to check the research and see possible problematic situations that occurred in the study and to find solutions. They provided that explanation in both pre- and post-interviews. Therefore, the analysis indicated there is not much difference between pre- and post-interviews. Overall, the analysis suggests that the teachers' understandings of engaging in arguments from evidence did not improve in the program.

Teachers' understandings of engaging in argument from evidence showed differences with the Framework. While the Framework makes connections between using argumentation, reasoning skills, and justifying a claim, the teachers focused on defending or providing the research and its components when somebody has contradicted arguments. This suggests the teachers' explanations and what Framework says about engaging in argument are different. In addition, although the Framework pointed out that it is very important to be critical and to identify the flaws in the arguments, none of the teachers included those points in their explanations.

Overall, the analysis indicated that teachers' understandings of science practices in the pre interview were not compatible with the conceptions of the professors and also the explanations in the Framework. While the professors more focused on why and how the practices were used throughout the research, the teachers' explanations were incomplete and did not include much information about why the practices were used or how they should be used in the research. The post interview analysis also indicated that teachers' understandings of the practices still were not compatible with the conceptions of the professors and also the explanations in the Framework. As it was found in the pre interview, their explanations did not include the expected points that were stated by the professors or in the Framework. This suggest, teachers' participation in the RET program did not improve their understandings of the science practices.

Ivette's Understandings of Science Practices

Ivette's understanding of fundamental concepts improved in the program. In the pre-interview, for Ivette fundamental concepts are the foundation of anything like the "foundation of a house." In the post-interview, she expressed that fundamental concepts are required to design the research; therefore, they are the foundation of the research. This explanation in the post-interview was aligned with the conceptions of the professors. For professors, to understand fundamental concepts is to know the fundamental concepts of research, which are the basic concepts of the content area and related to doing research or the process of research. This means her understanding at the beginning of the RET program was not related to science or research, but after the program she started to make the connections between the fundamental concepts and their relation to doing research. Although Ivette only mentioned fundamental concepts of the research, at least her understanding is aligned with the professors and improved in the program.

The other practice that she showed an increased understanding is to make use of the primary scientific research literature. In the pre-interview, she stated the literature provides the information about what has been done before. For professors, to make use of the primary scientific research literature serves as the basis for their research to identify what has already been found. In the post interview, Ivette made the connection between the literature and she said how it can be used in the research being done. She expressed that it helps to conduct the research and prepares the researcher for the things that will be seen during the research. The professors also stated that the literature is used to identify gaps in the knowledge; to construct hypotheses and research questions; and provide the norms, procedures, and standard measurements that are related to the research. Although she did not provide details like the professors in the post-interview, she made the connection between the literature and using it in the research. This suggests her understanding is aligned with the professors and showed an improvement.

In the pre-interview, while to identify a specific research question means to find an issue or a problem in order to find the answers; in the post interview, it means to identify a need or an aspect within the overarching research that needs to be investigated. She stated that the question should contribute to the overall research. This suggests Ivette did not make connections between the question and the objective of the study, or she did not explain how a research question can be identified like the professors did. This is important because for professors it means to determine a clear research question that is aligned with the objective of the study and based on what is missing in the literature. This suggests her understanding did not show much improvement, but in the post-interview she started to make the connections between her research, the research that has been done by the research group, and how her part can contribute to that.

In both pre- and post-interviews, she expressed that a research hypothesis is identified based on the literature, and it is the expectations about what is going to happen in the research. This suggests Ivette's understanding is aligned with the conceptions of the professors because they also think that a research hypothesis is the focus of the research, a testable explanation, the initial understanding of and the possible answer to the research question, and it should be identified based on the literature. Although the professors also stated that it is important to have a hypothesis at the beginning of the research, it is more important to be unbiased when the research is designed, and Ivette's understanding did not include those points. Overall, Ivette's understanding is somewhat aligned with professors, but her understanding did not improve in the program.

In both pre- and post-interviews, she stated that to design an experiment means to design a way or process to answer the research question or prove the hypothesis, so her understanding stayed same. This suggests Ivette did not provide any ideas about the identification of the variables in the design of the experiment and the importance of the scope of the research. This point is important because for professors the scope of the research should be flexible if the hypothesis needs to be revised. These explanations were not identified in Ivette's interviews. Therefore, her understanding of the design an experiment did not indicate an improvement.

When she was asked what it means to understand the importance of controls, in both pre- and post-interviews she stated control helps to see the changes, the variations, and the effects in the research, and it helps to compare the results of the research. The professors also stated that control serves as a baseline for comparison in order to come up with a conclusion. Although her understanding is good about this point, in both interviews she only talked about the control group, rather than the controlled variable. However, professors stated the differences between control group and controlled variable, but she did not state those differences. Also, the professors think it is important to be able to decide whether it is required to use them depending on the nature of the investigation, but Ivette did not mention that in her explanations. This suggests although her understanding is not totally same as the professors, there are some similar points, and it did not change in the program.

In the pre-interview, Ivette stated that to make observations is more related to the visual properties of the research such as the color, shape, or size, and it means to use the senses to gather information. Data collection is to take measurements and record them. In the post-interview, she emphasized that making observations is to check what is going on during the investigation and data collection is gathering the numbers and information. The professor interview also indicated that there are differences between making observation and collecting data. This suggests that Ivette was able to distinguish the differences between data collection and making observations. Although the professors also stated that to make observation and collect data is different, they should both be unbiased and accurate in order to have reliable research. Ivette did not mention that in her explanations. In the post interview, she especially started to point out the importance of making observations for checking the things that may cause problems in the research. The professors also think that making observations is more related to the quality control of the research and it helps to realize the problems and to see what went wrong in the research and find solutions to them. So, Ivette also pointed this out in the post interview. Overall, her understanding indicated an improvement in that practice.

At the beginning of the RET program, for Ivette to analyze numerical data means to find out the meaning and the explanation of the data, and to explain the reasons if the data did not show the expected measurements or results. She expressed the same ideas in the post-interview and added data analysis is very important and the heaviest part of the research because it is used to make the conclusions of the research. On the other hand, the professors think that it means to use statistics to find a trend in the data, to describe how a physical system is behaving, to make comparisons of the treatment and control samples, and to look at the power of the results, but none of these explanations were found in Ivette's answer. Although her understanding was almost same at the beginning and at the end of the program, she at least started to make connections with the data analysis and conclusions of the research.

One of the biggest differences in Ivette's understanding was seen in interpreting data practice. While in the pre-interview she stated it means to explain why the expected or unexpected results are reached in the experiment, in the post-interview she expressed that after data analysis it means to go back and see if the data and results support the hypothesis or not. The professors also think that it means after data collection looking at the data to find out whether the data support the hypothesis. So, this suggests her understanding improved in the program. The professors expressed that in the case of the hypothesis being rejected, it is the ability to explain the reasons for why the hypothesis does not match with the data; and based on the explanations, it is to make decisions. Although Ivette expressed a similar explanation in the pre-interview, she did not state that in the post-interview.

When she was asked to explain what it means to reformulate the original hypothesis in both pre-and post-interviews, for her it means to find another way if the hypothesis is not viable or is not possible to prove. In the post-interview, she also said it means to change the way of the research to prove the hypothesis, but the professors did not state that in their explanations. Instead, they said the researchers should be ready to test another aspect of the research. In the post-interview, she added that it means to change the hypothesis to find the answers. For professors, it also means to come up with a different explanation of the results, and create and test a new hypothesis when the data do not match with the original one. This suggests her explanation is aligned with what professors said, and that is the only idea that showed an improvement

For relating results to the bigger picture practice, in both pre- and post-interviews Ivette expressed that the specific research that she did is part of the whole research for improvement and relating results means to use the results of one part of the research to help the overall study. In the post-interview, she also stated it means to know how the results of the research contribute to the overall research by providing the information that is needed. This suggests her explanations in both the pre- and post-interviews were focused on the research part that she did and the importance of how her experiments will contribute to the overall research that has been done by the graduate student and professor, rather than how it will contribute to the literature or the field. This is important because the professors think that it means to provide explanations about how the research makes contributions to the research field and literature by adding new knowledge that can advance the field, but Ivette's explanation in both interviews did not make the connection between the results and its contribution to the literature. Therefore, her understanding of relating results to the bigger picture did not indicate an improvement.

For orally communicating the results of the research practice, in both pre- and post-interviews Ivette stated it means to explain what has been done in the research and what results are obtained. This suggests both Ivette and the professors think oral communication is being able to speak about the research. In addition to that, in the post-interview she specifically explained the importance of the effective communication based on the audience. She thinks that the communication should be based on the background of the audience in order to be more understandable by them. This suggests her experience about communicating the research in the RET program affected her understanding because in the post-interview she referred to the poster session and said she changed her way of explanation based on the background of the people. Although the professors think it should be done in a way that is communicable to a discipline-specific audience at a higher level in national or international meetings, such as conferences or symposiums, as well as in informal settings such as lab and research group meetings, Ivette did not state those ideas in her explanations. Overall, her understanding did not indicate much improvement on that practice.

In both pre- and post-interviews, Ivette's understanding of writing a scientific report of research means to put all the components of the research together in order to inform the people what has been done and the results of the research. This suggests Ivette made connections between the report and informing people about the research. This is important because for professors the purpose of the research report is disseminating the knowledge in a specific format in order to provide information to the people. She also specified that the report should be well written so other people can understand the research. Although for the professors scientific reports that have new findings move the field forward and the ones that do not have new findings inform the literature, Ivette's understanding did not include that explanation. Overall, her understanding did not indicate an improvement from the beginning to the end of the program.

When she was asked what it means to think independently, in both the pre- and post-interviews she expressed that it means to have your own ideas about the research and taking the chance on it. In the pre-interview, she also emphasized that it means to have a different point of view from other people and seeing the things in a different way when there is a problem during the research. Although the professors' conceptions include how independent thinking can be used in research, such as looking for connections and trends in order to see how the research process might be affected; predicting what may occur; making critical decisions; thinking about the reasons of the problems; finding solutions and producing new knowledge, Ivette did not mention any of these ideas in her explanations. The analysis suggests her understanding stayed the same in the program.

Regarding models, while in the pre-interview her answer focused on the idea that models are visual tools to understand, in the post-interview her answer focused on the model that she used in the RET program for her research. She said it can be a simulation of the conditions and helps to control what is going on in the research. In the post-interview, she also mentioned the accessibility of the models because they allow seeing the conditions of the things that are difficult to access. The Framework also states that models are explicit representations that are in some ways analogous to the phenomena. This suggests her understanding improved in terms of the kind of the models and how they can be used. She did not explain anything about to what extent models can explain the phenomena. Although the Framework emphasizes that models help to predict the behavior of the phenomena, understand deeply the science, and improve scientific reasoning, Ivette did not make those connections.

Ivette's explanations about using mathematics and computational thinking indicated an improvement. The biggest difference between the pre- and post-interview is the emphasis on the data analysis. While in the pre-interview she did not mention anything about the data analysis, in the post-interview her explanation is based on analysis of the data. Although in the pre-interview she mentioned the numbers and quantities that can be obtained in the experiments, she did not mention anything about the analysis. Additionally, in the post-interview she said mathematics is used in the data analysis. This connection is very important because the Framework especially focuses on the idea of mathematics, and computational thinking is used in statistical analysis of the data. The Framework also states that it is used in visual forms such as graphs, charts, tables, and figures to test relationships between variables, but Ivette did not state that in her explanation.

So, overall there is an increase in her understanding, but she still needs more improvement in order to demonstrate a complete understanding of using mathematics and computational thinking.

For constructing explanations practice, her understanding showed an improvement as well. In the pre-interview, for her this is scaffolding and building on little by little to understand things easily. Her answer was about how she explains the things to her children. In the post-interview, she stated it is to explain the data and what you obtain from the research. This suggests her understanding at the beginning was not research specific, but in the post-interview it was more scientific. She makes the connection between the constructing explanations and explaining the data because the Framework also states that the explanations are constructed based on the data. However, this is the only point that is aligned with the Framework because she did not state anything about scientific theories, models, representations, and primary and secondary evidence in order to support or not support the arguments about phenomena as it is explained in the Framework. In addition, although the Framework states it is explaining cause and effect relationships between the variables and finding the strengths and weaknesses of the ideas, her explanations did not include any information about that. Overall, her understanding indicated an increase.

In Ivette's pre-interview, to engage in argument from evidence means to defend the point of view and the results of the research by gaining evidence confidently and certainly. In the post-interview, she was still thinking it means to defend the data and results by using evidence. In the post-interview she also emphasized that it is not only sharing the data and results, because it should be done in a healthy way to get the conclusions in order to solve the problems. Although the professors think it means to use argumentation and reasoning skills to make a justified claim and is related to becoming a critical consumer of science, none of these ideas found in her explanations. This suggests her understanding is not in the expected level in both interviews and did not show an improvement.

Overall, Ivette's understandings of some of the science practices indicated improvements in the RET program because her post-interviews explanations were more aligned with the professors' conceptions and with the explanations in the Framework. Although her understanding indicated an increase in some practices, the analysis also suggests that she still needs improvements on most of the practices because the important components of the practices that were stated by the professors and the Framework were missing in her explanations.

Ashlynn's Understandings of Science Practices

In Ashlynn's pre-interview, to make use of the primary scientific research literature means to look at other peer reviewed articles to see what others have found and understand how they relate to the hypothesis or question that is being investigated in the research. This explanation is aligned with the professors' because they also think literature serves as the basis for their research to identify what has already been found. Both the professors and Ashlynn stated that the literature helps narrow down and focus the research question. The professors also think that the literature provides the norms, procedures, and standard measurements that are related to the research, but she did not provide those explanations. In the post-interview, for her it means to read the journal articles and talk to the experts about the research. Her answer in the post-interview was weaker than in the pre-interview. Overall, her understanding indicated some similarities with the professors, but in the post-interview she did not indicate an improvement.

A similar situation was seen when she was asked what it means to identify a question for investigation. While in the pre-interview for her the question should identified based on the literature and what you know about the research, in the post-interview she only expressed that it means to pinpoint exactly what one is looking for in the project; and it is a one sentence claim or a question that needs to be answered. Her explanation is better in the pre-interview than in the post-interview because the professors also expressed a research question is identified based on what is missing in the literature. Although the professors also stated that a research question should be aligned with the objective of the study, Ashlynn did not express that in her explanations. Overall, her understanding did not indicate an improvement.

Her understanding about the research hypothesis indicated similar findings. In the pre-interview, for her it means to narrow down what you would specifically like to investigate. In the post-interview, she explained that it means to find a question or a hypothesis that is basically the objective for doing research. Ashlynn did not state most of the ideas that were found in the professors' interviews. For instance, although the professors think a research hypothesis is the focus of the research, a testable explanation, the initial understanding, and the possible answer to the research question, none of these ideas were found in Ashlynn's explanations. She also did not make connections between the literature and formulating the hypothesis. The only difference is in the post-interview she mentioned the connection between the hypothesis and the objective of the research. Overall, her understanding did not indicate much improvement.

In both the pre- and post-interviews, Ashlynn felt to design an experiment or theoretical test of the hypothesis means to set up an experiment to test the hypothesis. This suggests, in her explanation she just repeated the question. She did not state any ideas about determining the steps of the research to follow and identification of the variables as it is stated by the professors. In addition, her explanations did not include any information about the scope of the experiment like the professors stated. Therefore, overall her understanding is not aligned with the professors and there is not an improvement in her understanding.

When she was asked what it means to understand the importance of controls, in both interviews for Ashlynn it means to understand the variables that may affect the experiment and control them as much as possible. This suggests she only thought about the controlled variable and did not explain the control group situation. Although her understanding is good about this point in both interviews, she only talked about the control group rather than the controlled variable. In addition, while the professors state that control serves as a baseline for comparison in order to come up with a conclusion, she did not mention that. Also, she did not state the differences between the control group and control variable and the importance of using the control. This suggests her understanding did not improve in the program.

For Ashlynn, in both pre- and post-interviews to make observations and collect data mean to record the observations and see what happens in the experiments. In the pre-interview, she also stated that making observations is more than just looking; it is to see whether any variable is overlooked. This suggests that although in the pre-interview she emphasized the meaning of making observations, in the post interview she did not state that. The analysis also indicated that she did not explain the differences between making observations and collecting data and the importance of unbiased and accurate observations. The professors stated that these points are important. Overall, her understanding did not indicate an improvement on that practice.

In both pre- and post-interviews, for Ashlynn to analyze data means to put the data into a spreadsheet and make graphs and charts. In the post-interview, Ashlynn thought it means to understand what the data mean and to find patterns in the data, but she did not state any ideas about the purposes of the data analysis. For instance, the professors stated that it is to use statistics to find a trend in the data, to describe how a physical system is behaving, to make comparisons of the treatment and control samples, and look at the power of the results, but her explanations did not include these ideas. This suggests her understanding needs improvement and did not indicate an increase in the program.

Her understanding of interpreting data in the pre- and post-interviews was totally different. In the pre-interview, for her it means to see what is coming out of the data and what patterns are found from the data. Also, she expressed the interpretations should not be biased. In the post-interview, she stated that it means to see whether you can confirm, deny, or discard your original hypothesis. This means her understanding in the pre-interview was very similar to her explanation about the data analysis, but in the post-interview her understanding focused on the hypothesis. This suggests there is an improvement in her understanding because the professors also think that it means to find out whether the data support the hypothesis. The professors also expressed that it is the ability to explain the reasons for why the hypothesis does not match with the data and to make decisions, but Ashlynn did not state that in her explanation. Overall, her understanding improved but she needs more improvement because the important components of the practices that were stated by the professors were missing in her explanations.

Her understanding about to reformulate the original hypothesis did not change in the program. In both the pre- and post-interviews, for her it means to retool or reword the hypothesis if the data and the analysis do not answer the research question, and to change the hypothesis to get more precise explanation out of the data. This explanation is aligned with the professors because they also think it means to come up with a different explanation for the results, and create and test a new hypothesis when the data do not match with the original one. Although the professors expressed that the researchers should be ready to test another aspect of the research, Ashlynn did not state that in her explanations. Overall, her understanding did not improve in the program.

In the pre-interview, for her big picture is the big trend of the research, and relating the results to the bigger picture means to see whether the research data fit in line with the big trend. In the post-interview, for her it means to apply a small model to a bigger global picture to understand what is going on. This suggests her understanding in both interviews was different but did not show an improvement. In addition, her explanations in both the pre- and post-interviews are not compatible with the professors' conceptions because for the professors it means to provide explanations about how the research makes contributions to the research field and literature by adding new knowledge that can advance the field. This suggests she did not make the connection between the research and its contribution to the literature. Therefore, her understandings of the big picture did not increase in the program.

Ashlynn's understanding of orally communicating the results of research did not indicate a big change because in the pre-interview she expressed that it means to talk about and explain the research and the results to people in a conference and to answer questions about the research. In the post interview, she expressed it means to verbally explain the research, hypothesis, and the experiments to the people. Although the professors also suggest that it means to communicate the research to a discipline-specific audience at a higher level in national or international meetings such as conferences or symposiums, they also stated that it means to communicate the research in informal settings such as lab and research group meetings, but Ashlynn did not state the informal settings in either the pre- or post-interviews. Overall, her understanding did not indicate much improvement on that practice.

Her understanding of writing a scientific report of research was more related to the structure of the report. In the pre- and post-interviews, she stated that it means to put the research components such as an abstract, research hypotheses, the methods, results, and analysis in a specific format like a journal article. In addition, in the post-interview she stated that the poster they prepared in the program is a kind of scientific research report. This suggests her understanding is more related to the structure of the report instead of the purpose of the research report. The professors commented on the structure of the report, but they also explained why the reports are written. While the professors stated that reports are written to disseminate the knowledge, add new findings, move the field forward, or inform the literature, Ashlynn did not emphasize those purposes in her explanations. Overall, her understanding did not improve in the program.

Her understanding of thinking independently was different in the pre- and post-interviews, but did not indicate an improvement. In the pre-interview, for her it means taking and knowing other people's understanding of a subject but then still being able to find your results, interpret your thinking, and to have your own thoughts and interpret them in a different way. For the professors, it means to be able to take the responsibility of the overall research from the formulation of the idea or the hypothesis to the dissemination of the knowledge. On some points her explanation is similar to what professors said. In the post-interview, she emphasized that it means to read the literature in order to have a good basis to understand the research better, but her explanation is not aligned what the professors think because they also expressed that it means to make critical decisions about the research based on your observations and what other people have done, to think about the problems, and to find the solutions in order to produce new knowledge. This suggests her understanding did not improve in the program.

In both the pre- and post-interviews, for her to use mathematics and computational thinking means data analysis and trying to understand what the data mean. The connection that she made with the data analysis is good in both interviews because this is also stated in the Framework. While in the post-interview she referred to the research she did in the program and added that it also means to switch the data into a more comprehensible format and using equations to understand the data, she did not provide any explanation about presenting the data in visual forms such as graphs, charts, tables, and figures to test relationships between variables and to express relationships and quantities in appropriate mathematical forms as it is explained in the Framework. The only difference she made in the post-interview is the connection to her data analysis and using equations. Other than this, her understanding did not show much improvement.

In both the pre- and post-interviews, she expressed that models represent and simplify things and they help to understand them easily. The Framework (2012) also states that models are explicit representations that are in some ways analogous to the phenomena. Therefore, this suggests she made the connection between the models and representations. She also thinks that models cannot explain everything completely but they do a good job in simplifying and understanding the things. The Framework also emphasizes that models do not correspond exactly to the more complicated entity being modeled because they cannot bring certain features into focus, while minimizing or obscuring others. This suggests both Ashlynn and the Framework emphasized the validity of the models. Although the Framework also states that models help to visualize, predict the behavior of the phenomena, understand deeply the science, and improve scientific reasoning, Ashlynn did not express that in her explanations. Overall, her understanding of models is aligned with the Framework, but still needs some improvement.

In the pre-interview, for her constructing explanations means to understand the meaning of the data and the results in a comprehensible way and to apply it in a real-world situation. In the post-interview, she expressed it is to understand the data and interpret it and to make conclusions and assumptions based on them. Although the connection she made between the explanations and understanding the data is aligned with the Framework, her explanations are missing several important points as well. For instance, the Framework expresses that explanations are constructed by using scientific theories, models, representations, data, observations, and primary and secondary evidence. It also means to explain cause and effect relationships between the variables and evaluate and critique the explanations, but none of these ideas were identified in her understandings. This means her explanations in both interviews were different but do not indicate the expected ideas and did not improve in the program.

Her understanding of engaging in argument from evidence is different in both interviews. In the pre-interview, while she thinks it means to have an open dialogue with the experts in order to make them to understand the research, in the post-interview she expressed it means to argue for or against something based on a strong knowledge base and background information. This suggests her explanation does not show how the argument will be constructed. For instance, the Framework states that it means to use reasoning skills to make a justified claim about a scientific phenomenon. In addition, although the Framework emphasizes that it means to become a critical consumer of science by using critique and evaluation, Ashlynn's explanations do not include those connections. The analysis suggests that although in the post-interview she made the connection to the background information, most of the important ideas that are explained in the Framework are not identified in her explanations. Overall, there is not much improvement in her understanding.

Overall, the analysis suggests that Ashlynn's understandings of most of the science practices did not indicate make an improvement from the beginning to the end of the program. She needs improvement because her understandings of most of the science practices are not aligned with the professors. Although some of her explanations are compatible with the professors' conceptions and with the explanations in the Framework, she stills needs improvements on those practices as well.

Research Question 2: Overall Findings

The analysis indicated that the teachers' understandings of formulating a research hypothesis, the importance of controls, reformulating the original hypothesis, relating results to the bigger picture, writing a scientific report of research, thinking independently, and developing and using models did not indicate much improvement from the beginning to the end of the program. Although for some of those practices they have similar explanations as the professors and with the Framework, most of their understandings are not compatible with the professors' conceptions and the explanations in the Framework. It is likely that teachers' understandings would affect the way that they conceptualize them for their students. Therefore, they need to improve their understanding of those practices in order to prepare their students to engage in them. Overall, the teachers' understandings of identifying a specific research question, designing an experiment, interpreting data, constructing explanations, making observations and collecting data, orally communicating the results of research, using mathematics and computational thinking, and analyzing numerical data did not show much improvement, but only a few teachers' understandings indicated minimal change on some aspects of those practices. Therefore, the teachers did not have complete and thorough understandings of those practices. The teachers' understandings of the fundamental concepts of research and making use of the primary scientific research literature indicated more improvement than the other practices from the beginning to the end of the program. The teachers' understandings of orally communicating the results of the research and reformulating the original hypothesis indicated the ideas most similar to the professors; and the teachers' understandings of developing and using models has the most similar ideas with the Framework.

Overall, the results suggest that teachers' understandings of most of the science practices are not aligned with the professors' conceptions and the explanations in the Framework, and they did not show much improvement after they participated in the RET program. Some of the practices indicated minimal changes on some aspects, but the teachers still need more clear understandings about them since their understandings would affect the way that they conceptualize them for their students when they prepare the students to engage in them.

Research Question 3: What are the Sources of Differences in RET Teachers' Change in Their Understandings of Science Practices and Abilities to Engage in Science Practices?

In this section, first I present the graduate student interview, teacher post interview and teacher post survey analysis to find out the sources of differences in teachers' abilities to engage in science practices. Then, I present the results of the sources of differences in RET teachers' change in their understandings of science practices interview analysis.

The Sources of Differences in Teachers' Abilities to Engage in Science Practices

In order to find out the sources of differences in teachers' abilities to engage in science practices, the graduate student interview, teacher post interview, and teacher post-survey were analyzed. Below, I first report the findings from the analysis of the graduate student interview about why they think teachers' abilities to engage in science practices improved or did not improve in the RET program. Then, I present the teacher post-survey analysis results along with the teacher post-interview analysis. At the end, I put together the overall findings of those three data sources to answer the research question.

Graduate students' perceptions of RET teachers' abilities engaging in science practices interview. At the end of the RET program, the graduate students completed a survey that allows them to rate the abilities of the teachers that they worked with. Then, based on the results of the survey, they were interviewed after the RET program was completed. In the interview, the graduate students were asked to explain why they think the teachers' abilities to engage in science practices improved or not. The analysis indicated that while some graduate students think the teachers they worked with improved on the practices, others think some teachers did not show an improvement on some specific science practices. Based on the analysis, three main reasons were identified to explain the improvement of the teachers on their abilities to engage in science practices, and four main reasons were found to explain why some teachers did not show an improvement.

Below, I first present the reasons they provided to explain why the teachers' abilities improved, and then the reasons that explain why some teachers did not show an improvement are presented.

*The graduate students' perceptions of why the teachers' abilities to engage in science practices improved***.** The first reason is being involved in the research. The graduate students think that being involved in the research and having experience helped the teachers to improve their abilities to engage in science practices. They pointed out that teachers' engagement in those practices while they were doing research in the RET program allowed them to get more experience and improve their abilities. For example, they think that the teachers who actually collected and analyzed data for their research improved because they practiced more and learned how to engage in data collection and analysis. For instance, one of the graduate students expressed her opinions as below:

> Make observations and collect data, this one definitely she learned a lot in the first couple of weeks. Later, she was able to do her own tests and collect her data we did not description for me to be able to review it and use it (Graduate student interview, 9/4/2013).

Another graduate student explained that the teacher improved on the data collection:

> Analyzing numerical data, the teacher was a lot more involved in analyzing the numerical data and she helped me make the graphs, the poster and asked lots of questions to make sure that she understood why the data came up the way it did. So, I feel like she improved quite a bit in that area just based on the fact that she asked lots of questions and seemed to demonstrate mastery of that knowledge. (Graduate student interview, 8/29/2013).

Some graduate students think that the teachers improved on orally communicating the results of their research because they were able to explain what happened in the experiments in the poster presentation and in the lab tours. The graduate students stated some teachers' abilities to make use of the primary scientific research literature improved because they reviewed the literature for their project. Similarly, some of the research studies in the RET program included the use of controls. This provided an opportunity for the teachers to get more experience about what kind of controls needed to be used in their experiments. Another example is related to teachers' improvement in their ability to engage in argument from evidence. The graduate students stated that the teachers talked about their research to the public in the poster session and in the program several times, therefore those teachers showed an increase in engaging in arguments from evidence and relating results to the bigger picture. They also think that as teachers got more experience in the program they learned how to formulate and reformulate a hypothesis, design an experiment, and think independently.

The second reason is the graduate students' help. They expressed that the teachers whom they mentored were coming up with their own ideas after having discussions with the graduate students; therefore, that helped the teachers to improve their ability to identify a specific question for investigation. The graduate students also pointed out that they sent several articles and reports to the teachers. They think that these sources helped the teachers to improve their ability to review the literature. In the interview, some graduate students stated that they gave a crash course in Excel and taught the teachers how to analyze data. Therefore, those teachers' abilities to analyze data and to use mathematics and computational thinking practices improved. They also pointed out the importance of the guidance and supervision the teachers had during the data collection. Most of the graduate students think the discussions they had with the teachers about the process of research helped to improve teachers' understandings of fundamental concepts, their ability to relate results to the original thoughts, interpret data, orally communicate the results of the research, and to formulate a research hypothesis. For instance, one of the graduate students expressed that the teacher's ability to interpret data improved in the program:

> And interpret the data, every time we did the experiment she sat down and we thought about discussed what is happening, what are we seeing, is it what we saw we were thinking hypothesis or is it not so I think she has great deal knowledge in that too. (Graduate student interview, 9/4/2013).

The third reason provided by the graduate students is reading the literature. They think that the literature helped the teachers to understand the fundamental concepts, how to identify a research question and hypothesis, and how to design the experiment. They also think that providing the literature helped the teachers to learn how to make a literature review.

The analysis also indicated that Ivette's graduate student stated that Ivette's ability to make observations and collect data practice improved because she actually engaged in this practice. She thinks Ivette collected her data during the research, and that helped her to learn how to collect data. The graduate student also expressed that the discussions she had with Ivette helped her to improve in identifying a research question for investigation, formulating a research hypothesis, designing an experiment, interpreting data, and constructing explanations. The graduate student explained that the following:

> So that one, identify a specific question for investigation, well I think she learned, she improved on that based on the fact that initially we were not really sure what we wanted her to do. She was learning, we kept discussing about the possibilities for experiments and she really had an input on what we are trying to do. And I think she is capable of doing developing questions or even identifying, you know, what we are doing, what is a question that we are trying to answer. (Graduate student interview, 9/4/2013).

The graduate student also expressed that Ivette's improvement in analyzing the data and using mathematics and computational thinking practices is related to the crash course she gave:

> And analyze numerical data, so this one I gave her like a crash course in Excel. So, I think she learned a lot from that, so that is why I answered quite a bit, at least for knowing like averages, standard deviation she understands that. Use mathematics, this part ties with the data. So, she got our crash course with Excel, so I think she is more than able to do math and computational thinking. (Graduate student interview, 9/4/2013).

Ivette's graduate student also emphasized that reading the literature helped Ivette to understand the fundamental concepts and constructing explanations.

Ashlynn's graduate student mentor stated that Ashlynn's ability to make observations and collect data improved because of her engagement in those practices during the research:

> Since she was the one that was related with the data collection, I think that she was able to collect the data and she got a lot of practice in the lab. And I think she had as much as experience with that before by the end of the summer, she had a lot of experience. (8/29/2013).

Overall, the results suggest that actual involvement in the practices, having discussions with the mentors, engaging in the crash courses, and reading the literature help to improve the teachers' abilities of the science practices.

The graduate students' perceptions of why some teachers' abilities to engage in science practices did not improve. Three main reasons that explain why some teachers' abilities did not improve in the RET program emerged from the analysis of the graduate student interview.

The first reason is the structure of the program and the activities in which the teachers were involved. Some teachers did not have the opportunity to be involved in the science practices because the research projects in which they participated were not hypothesis driven. For example, some teachers did not have the opportunity to formulate a research question or a hypothesis; to design an experiment; to collect, analyze, and interpret data; and use controls, models and mathematical and computational thinking because the nature of the projects in which they participated were more related to lesson plan development. For the graduate students, that might be one of the reasons which explain why some teachers' abilities to engage in science practices did not change in the program. On the other hand, some projects did not include all science practices, even though they were hypothesis driven. Thus, the teachers who participated in those projects did not improve much on those specific practices. For example, some teachers' research projects did not require teachers to develop and use models. Similarly, most of the teachers did not reformulate a hypothesis because their data supported the original hypothesis. In addition, the teachers did not write a scientific report other than their posters. That means some teachers did not improve on those practices because they did not have an opportunity to engage in them. The other explanation that was given by several graduate students was the limited time of the program. The graduate students pointed out that the time of the program was very short. Therefore, it is not realistic to improve each science practice at the same level. It is important to emphasize that although the time is important, the amount and the quality of the work that the teachers are exposed to in that time is more important for improvement.

The second reason is the interest and effort of the teacher. The graduate students reported that some teachers were not interested in participating in all the research activities. For example, some teachers did not show an interest in discussing the papers that the graduate students assigned, they did not come up with any ideas about the research for improvement, and they did not read literature that could help them to improve. One graduate student especially stated that the teacher did not analyze the data because she was not interested in doing that. Another graduate student stated that the teacher with whom she worked was only task-oriented and only followed the directions that were given by the graduate student. Therefore, she did not think about why they did or didn't do the things during the experiments. The same graduate student pointed out that the teacher did not put any effort into understanding the concepts, even the she explained them to the teacher. That teacher did not read the literature, ask questions, or engage in understanding the concepts. Therefore, she did not show much improvement on those practices.

The third reason is related to the graduate students. In the interview, the graduate students explained that they sometimes gave the information about the research directly to the teachers; therefore, the teachers did not necessarily get involved in those practices. For example, most of the graduate students gave the research questions or the hypotheses directly to the teachers without encouraging them to come up with these themselves. Therefore, some teachers did not identify a question for their research. Similarly, in general, the graduate students designed the experiments and the teachers only followed the directions that were given by their mentors. Therefore, those teachers did not necessarily think independently about their research and how to design the experiments. Also, some graduate students did not require the teachers to do a literature review, so those teachers did not have enough experience with that practice.

Ashlynn's graduate student stated their research did not require Ashlynn to reformulate the original hypothesis, think independently, and develop and use models; therefore, her ability to engage in those practices did not improve in the program. The graduate student also emphasized that Ashlynn's ability to engage in identification of the research question for investigation and designing experiment practices did not improve because she directly gave the research question and the procedure of the design of the research to Ashlynn. She expressed that, "Designing an experiment, they did not really design an experiment and they were doing what I told them to do. So, it is hard to say that they really had a very mastery of designing an experiment." Therefore, Ashlynn did not engage in those practices and her ability did not improve. In addition, for the graduate student, while Ashlynn's ability to analyze and interpret data did not improve because she was not interested engaging in those practices, her ability to relate results to the bigger picture and engaging argument from evidence did not improve because she was task oriented. Concerning data analysis she said, "Analyzing numerical data, that was a little bit complicated. Ashlynn was not interested in being involved in the process, so I don't think that she improved very much with analyzing the numerical data." For data interpretation practice she stated as below:

> Interpreting the data is the same. She was not super interested in being involved with that, mostly left it up to the other teacher and so I don't think that she understood as well why the numbers came out the way they did. (Graduate student interview, 8/29/2013).

Ivette's graduate student also stated that their research did not require them to reformulate their hypothesis; therefore, Ivette did not show much improvement on that practice. She said, "We did not get to reformulate the original hypothesis because we saw what we expected, but I think she is able to do that as well".

Overall, the graduate students think that the structure of the program, the activities in which the teachers are involved or not involved, the interest of the teacher, and the direct information that is given by the graduate students may prevent improvement in the teachers' abilities to engage in science practices.

Teachers' abilities to engage in science practices post-survey. In the RET program, the teachers completed a pre-, mid-, and post-survey that allows them to rate their abilities to engage in science practices. In the post-survey, they were also asked to explain why they think their abilities improved or did not improve in the RET program. The analysis indicated that while some teachers think they improved on all of the practices, the other teachers think they did not show an improvement on some specific science practices. Based on the analysis, three main reasons were identified to explain the improvement of the teachers in their abilities to engage in science practices, and three main reasons were found to explain why the teachers did not show an improvement.

Below, I first present the reasons they provided to explain why they think their abilities improved, and then the reasons that explain why their abilities did not show an improvement in the program are presented.

*Teachers' perceptions of why their abilities to engage in science practices improved***.** The first reason is being involved in the research and practice improved teachers' science practices. As they got more experience within the project they gained more understanding of the fundamental concepts of the research. The teachers reported that by working in the research, they felt they are more able to identify a question about their study, design an experiment, collect data, use controls, analyze data, and relate results to the bigger picture. Some teachers think that the practice and experience in the program improved their oral communication practice. For example, one teacher stated that, "Having so much practical experience with the nitrogen cycle helped me to better orally communicate our results." In addition, some teachers also think that through the research experience they gained a better ability to construct explanations of their specific content area.

The second reason provided by the teachers who think their science practices improved is the discussions they had with the graduate students. The teachers think that working with the graduate students helped them to improve their science practices. For example, they think the discussions with the graduate students helped them to understand the fundamental concepts, to access and read the literature, and to investigate a research question related to their project. One teacher stated that, "My ability improved, thanks to the literature, the support and help that my mentors provided me." Another teacher mentioned that, "With the support provided by my mentors, now I am feeling more comfortable to identify questions for investigation related to the overall recirculating aquaculture systems (RAS) research." They think the graduate students helped the teachers in the design of their experiments, as well as the poster preparation. One of the teachers mentioned that, “This was a great deal to design my experiments; however I did receive many suggestions and recommendations from my mentors.” Some teachers think that their graduate mentor and faculty mentor pressed them hard to improve how to engage in arguments. In addition, for some teachers the discussions they had with the graduate students improved their abilities to formulate a research hypothesis, and collect and analyze data as well.

The third reason is to learn a new topic, new methods, and new techniques in the program. Some of the teachers pointed out that the topics that they were involved in the research were new to them, but they were exposed to these new areas in the RET program and learned those topics. They also think that RET program helped them to understand the new methods and techniques that are used to do research. They stated that they learned new data collection and analysis methods, and they learned how to use different techniques. Those experiences helped them to understand fundamental concepts of the topic, to formulate a research hypothesis, design an experiment, use the controls in the research, to relate results to the bigger picture, to orally communicate the results of their research and to develop and use different models.

Ivette thinks that her ability to identify a specific question for investigation, formulate a research hypothesis, design an experiment, communicate the results of the research and think independently practices improved because of the support and help of her mentors. For instance, for her ability to identify a specific question she stated that, “With the support provided by my mentors, now I am feeling more comfortable to identify questions for investigation related to the overall recirculating aquaculture systems (RAS) research.” Also, for her ability to design an experiment she expressed, “My ability improved thanks to the support and help provided by my assigned mentors as well as the whole research team that were always available to answer the questions and guide me with my concerns." She also thinks that her ability to use models improved because in her research she actually used an RAS model.

Ashlynn thinks that her ability to design an experiment and make observations and collect data practices improved because she learned how to engage in them from her graduate student mentor. She stated, "I collected data in a new way with the specific test that my graduate student collected. This gave me more experience testing and observing the nitrogen cycle." In addition, she thinks that her ability to orally communicate the results of research improved by actually practicing that in the program. Similarly, she stated that her ability to use models improved because she used a model for her research. She stated, "My graduate student's project was to set up a model of the nitrogen cycle in an aquaponic tank. This experience helped me develop and use a model to represent the nitrogen cycle."

Overall, the teachers think that being involved in the research, actually engaging in the practices, the discussions, help and support of the graduate students, and learning a new topic and techniques helped them to improve their abilities to engage in science practices.

*Teachers' perceptions of why their abilities of some of the science practices did not improve***.** The first reason provided by the teachers who worked in the research projects is that it did not include some of the practices. Those teachers think that they did not have an opportunity to master some of the science practices. For example, some of the research projects did not include to design an experiment; to collect, analyze and interpret data; and to reformulate a hypothesis. Teachers mentioned that because the nature of the research was not scientific, and they were not involved in those practices during the program. In addition, some teachers also mentioned that their projects did not require them to use controls in their research, or mathematics and computational thinking. For example, one teacher said, "My research essentially didn't have controls other than reviewing grades for the previous classes that did not use these techniques to teach their subjects.” She thinks that that is the reason why she did not improve on using controls in the research.

The second reason is the past experiences of the teachers. Some teachers think that they already mastered their practices before the RET program; therefore, the program did not make additional improvement. Those teachers stated that they already had a strong background in literature review, identifying a specific question, and formulating a research hypothesis. For example, one teacher said, “I have used primary scientific research a lot in my past so I don’t think that skill went up. I did use it again for this project, but I don’t think it changed my ability to use it.” Some of the teachers pointed out that they got those experiences when they were in graduate school. For example, some teachers think that in the graduate school they learned how to design an experiment or theoretical test of a hypothesis, collect data, analyze data, relate results to the bigger picture, use controls, orally communicate the results of the research, write a scientific report, think independently, and develop and use models. One teacher said, “It really did not change much because I had already studied at the graduate level and understood how to identify a specific question for investigation.” In addition, some of the teachers stated that being a science teacher requires using those practices in the classroom; therefore, they already know how to identify a question or hypothesis, construct explanations, interpret data, and use controls in the research. For example, one teacher said, “I teach the nitrogen cycle and feel comfortable thinking of a particular question to research within the cycle.” Another teacher stated that, “Since I am a science teacher, I have to come up with hypotheses all the time for my lessons and help my students formulate them as well.”

The third reason concerns the graduate students because of some of the information about the research directly given by them; therefore, the teachers did not have the opportunity to master those practices. For example, some teachers mentioned that their research questions or the hypothesis were given directly by the graduate student mentors, so they did not have to come up with another one.

Ivette stated that she did not use controls and did not reformulate the hypothesis in her research, so her ability to understand the importance of controls and reformulate the original hypothesis did not improve very much. Also, Ashlynn stated that she still needs improvement especially in analyzing data, using mathematics and computational thinking, writing a scientific report of the research, and engaging in argument from evidence because she needs more practice.

The analysis of both what graduate students and teachers think that being involved in the research and actually engaging in the practices is very important in order to improve teachers' abilities of the science practices. They think that active engagement provides opportunities to have more experience with the practice and therefore helps to master the ability. Also, both teachers and graduate students emphasized the importance of the support, help, and guidance of the graduate students to improve the teachers' abilities. They think that the discussions they had with the teachers and the crash courses helped the teachers to understand more about how to engage in the practices. In addition, while the graduate students think that the interest of the teacher is very important for the improvement, the teachers think learning new techniques, methods, and information help them to improve on the practices.

The analysis also indicated that both the teachers and graduate student think the activities and the structure of the research are very important because the projects that do not allow the teachers to engage in the practices do not help the teachers to improve. In addition, the teachers and graduate students think if the information for the research is directly given by the graduate students then the teachers do not necessarily engage in the practices. Therefore, this does not allow them to improve as well. Some teachers think they already learned how to engage in some of the practices in their previous experiences therefore they did not improve on those practices in the program. One of the graduate students stated that the teacher who had the low interest to engage in the practices did not show an improvement.

Teachers' understandings of science practices post-interview. The analysis of the teacher post-interview indicated similar findings as with the graduate student interview and the teacher post-survey. Although the post-interview was about the teachers' understandings of science practices, important findings were identified that explain why some teachers' abilities to engage in science practices improved or did not improve.

*The reasons that explain why the teachers' abilities to engage in science practices improved***.** The teachers who actively engaged in making a literature review, designing the experiment, collecting, analyzing and interpreting data, using controls, and orally communicating their research in the meetings and in the poster session stated they improved on those practices because of the experience they had in the RET program. They think active participation allowed them to learn how to engage in those science practices. Teachers also pointed out that the help they got from the graduate students increased their abilities during the RET program. For example, one of the teachers stated that her graduate student mentor sent different articles related to their research and that helped her to understand the research better:

The teachers also pointed out that reading the literature helped them to learn the information that was required for their research. They think that they learned the fundamental concepts and the background information about their research from reading articles, reports, or proposals. They also stated the literature review helped them to formulate their research question. For example, one teacher stated this as follows:

> I read a lot of articles in the program. I pretty much spent the first couple of weeks with like techniques and literature to read to kind of give me background of what she was doing, so I could use that knowledge to make my own question as far as what I want to do for the remainder of the program. (Post interview, 8/21/2013).

Another teacher stated the research literature that she was given by the mentor gave her the foundation of the concepts they used in their project.

Ivette stated that the weekly meetings helped her to see how to engage in argument from evidence. For example, she explained that in the post interview as follows:

> We had a meeting like every week on Mondays. It depends on the commitments the professor had but I noticed that everybody think their own results or whatever they were doing in that week. And the argument is a healthy argument for the common purpose of the research, that is something that I really liked because you don't see that all of the time. (Post interview, 8/16/2013).

She also stated that at the beginning of the research her mentor sent her articles. Although she thinks she still needs to improve on that practice, she said that helped her to make use of the primary scientific research literature. She said, “This summer, my mentor, she sent me a folder on the drop box which the research team has; they have like a lot of journals articles.” She also thinks her mentor helped her a lot in her research. She stated, “I had a lot of help from my mentor and she then gave me like a quick Excel training to analyze my data.” Similarly, she emphasized that she had discussions with her mentor about her research and asked questions about whether she needed to use any controls for her experiments, which helped her a lot in her project.

In the post interview, Ashlynn stated that she collected a lot of data for her research. She stated that as follows:

> So, we did water quality data and we tested our samples of water for five or six different quality tests like nitrate, nitrogen, phosphate, dissolved oxygen, all that kind of stuff. Total phosphorous, nitrate, chemical oxygen demand, nitrogen, ammonia, total nitrogen, and reactive phosphate for the six tests that we tested for every day. (Post interview, 8/6/2013).

The analysis indicates that her ability to collect data improved because of her engagement in data collection in the program. She also stated that although she did not read a lot of literature in the program, the articles that she read for her poster helped her to prepare the background section of the poster.

*The reasons that explain why the teachers' abilities to engage in science practices did not improve***.** Some of the teachers explained why they think their abilities did not improve in the program. Some teachers pointed out that they did not have an opportunity to engage in all or some of the science practices. Those teachers did not make a literature review; collect, analyze and interpret data; design experiment, and use controls. For example, one teacher said, "Not exactly, my research was more of an academic implementation research than a true scientific research. With the subject that I was given from my mentor it really didn't land itself to a hypothesis." Another teacher explained that:

> Well, that was the thing I kind of struggled with. I never was kind of given the opportunity to have a research question. So, I come up with the water conductivity thing

on my own which I came up with but I was not really supported to be able to really feasibly get this done the way it would be done". (Post interview, 9/23/2014).

One teacher mentioned that she did not involve in making literature review so much because she thinks they were not given a lot of information about it.

Ashlynn especially stated that she was not involved in the data analysis process because she thinks she is not strong in that part. This suggests that although she perceives her ability to analyze data is low, she did not try to learn how to analyze her data. In the post interview, Ivette stated that she did not use controls in her research and did not reformulate the hypothesis of her research because she got the expected results.

The analysis of graduate student interview, teacher post-survey, and post-interview indicated similar findings because they think actually engaging in the practices, the support, help and guidance of the graduate students, discussion with the mentors, and reading the articles helped the teachers to improve on the science practices. The teachers also think that the new information they learned in the program helped them to improve. The analysis also indicated that the research that does not allow the teachers to engage in the science practices, and the direct information given by the graduate students does not allow the teachers to improve. Some teachers also emphasized that they already learned how to engage in some of the practices, and therefore they think for those practices the RET program did not help them.

The Sources of Differences in Ivette's and Ashlynn's Understandings of Science Practices

In order to find out the sources of differences in teachers' understandings of science practices, Ivette and Ashlynn were interviewed again after all the interviews were analyzed. In this interview, they were asked why they think their understandings of science practices improved or did not improve in the RET program. Below, I report the findings from the analysis of this interview.

Ivette's interview. In the interview, Ivette was asked why there is an improvement on her understandings of the fundamental concepts, making use of the primary scientific research literature, making observations and collecting data, interpreting data, developing and using models and constructing explanations practices. She emphasized that the research group that she worked with helped her to understand those practices better. She stated that as below:

> One of the things that I believe it helped me a lot is I worked with a really good team. I have been working with my graduate student for a year now; and then I also worked with [the professors], and the preservice teachers that we are coming back for the program. And I am a person that likes to ask a lot of questions and I think that very crucial part of that improvement was the support and the research that I had for the program. Like, if I did not understand something or if I was not sure about anything related to the research or related to the program I knew who to go with and I knew I was going to the correct guidance or advice in terms of whatever question I had. I think that support from the program in general was very essential for that. (Post-Post Interview, 6/10/2014).

Ivette also emphasized that the help that she had from her mentor allowed her to pay more attention and to learn what the expectations were for the data collection and interpretation; therefore, she improved on those practices. She also stated that the experiences she had in the program were totally new for her because she was coming from a different culture as a nontraditional student. She thinks she learned very different experiences in the program.

Ivette also emphasized that she learned a new perspective about how to use journal articles and sources and which sources she can rely on for her research. Therefore, she thinks her understanding of making use of the primary scientific research literature improved. She also stated that it was a long time that she has not been in a research lab, so the RET program was a whole new experience and new world for her in terms of the methods and protocols. She thinks the experience helped her to develop her own experiments and work on them. In addition, she pointed out that seeing other graduate students' and teachers' projects helped her to see the things from a different perspective.

The previous analysis stated that Ivette's understandings of some of the practices did not indicate much improvement. When she was asked what might be the reasons for that she stated that she needs more experience on those practices:

> Maybe I did not work much on that aspect; I don't see any other reason for it to be honest. To be honest, I don't really know exactly the reasons why, that might be something that I will need to perhaps work more closely towards that. The understandings that I have in regards of those practices maybe I was thinking that is okay, you know, sometimes when you do things you think you are doing in right ways but you don't really pay much attention to, maybe that is one of the reasons why. I don't really know exactly. (Sources of difference Interview, 6/10/2014).

Overall, Ivette thinks that the research group that she worked with, the support that she had from her mentors, the research project that she participated, the literature, and the new knowledge and methods that she learned in the project helped to improve her understandings of the science practices. On the other hand, she thinks that her understandings of some of the practices did not improve because she needs to work more on those practices and gain more experience and knowledge about them.

Ashlynn's interview. In the interview Ashlynn was asked why there is not much improvement in her understandings of the science practices. She stated that the research she had in the RET program was not different than her previous experiences, and therefore it did not challenge her. In addition, she emphasized that the research was guided primarily by the graduate student. She stated that as follows:

> I think probably two reasons; number one is that I have a background in research, so what I was doing was not especially new to me. And I also think that some parts of the research were done for us so it was not necessarily us coming up with everything on our own. The research in the project was really guided by the graduate student (Sources of difference Interview, 6/4/2014).

She pointed out that if she had a bigger role in designing the experiments that might help her to improve more on those practices. She also stated that she had just graduated from the college, therefore a lot of the content was fresh in her mind. When I showed her the explanations she gave in the pre- and post-interviews she stated that they are low level explanations.

When she was asked why there is an improvement on her understanding of the interpreting data practice, she stated that, "Probably because I worked so much with data. That was really my main role in that internship. It was just doing test after test and working with data."

Overall, Ashlynn thinks that her understanding did not improve because the program was not different than her previous experiences, and the research was primarily guided by the graduate student, and therefore she did not engage in most of the practices. She thinks if she had been given more responsibilities in the research she might have improved more. In addition, she emphasized that she worked with the data more closely, so this helped her to improve on interpreting data practice.

The analysis indicated that Ivette's improvement on her understandings of the science practices is primarily based on the research group that she participated in. This suggests the support that she had from the graduate student and the professor helped her to gain more productive experiences and helped her to gain better understandings of the science practices. Ashlynn did not state those explanations in her interview. She underlined that her research was mainly guided by the graduate student, she was not given more responsibilities in the research, and therefore did not improve more.

Research Question 3: Overall Findings

The analysis indicated being actively involved in the research and having experience to engage in the science practices is very important because the teachers who had more experience by actually engaging in the practices mastered their abilities. Second factor that improved teachers' abilities is the graduate students' help. In the RET program, the graduate students worked with the teachers and helped them to understand their research. The teachers who had discussions with the graduate students about their research, read the literature that they assigned and attended the quick lessons that they gave improved on most of the science practices. The third factor is the literature review. The teachers who did a literature review showed an improvement on some of the practices including understanding fundamental concepts, identifying a specific question, formulating a hypothesis, designing an experiment and using the literature. In addition, the teachers who had weekly lab meetings also learned how to engage in arguments.

The analysis also indicated the factors that explain the reasons why some teachers' abilities did not show much improvement in the program compare to the other teachers. Some of the research projects were not hypothesis driven therefore the teachers who participated in those studies did not have an opportunity to actively engage in the science practices. The analysis also indicated that the teachers who had low level interest to engage in some of the science practices prevented themselves to improve more on those practices. In addition, the teachers whose graduate students directly provided them all the information that they needed for the research did not necessarily engage in the practices such as designing an experiment, identifying a research question and formulating a hypothesis. Therefore, that did not allow them to increase their abilities of the science practices.

The analysis suggests that the research group and how the teachers were guided in the groups are very important to improve the teachers' understandings of the science practices. The support that the teachers have in the group helps them to gain more productive experiences and better understandings of the science practices. In addition, the analysis indicated that teachers' active engagement in the practices also helped them to improve their understandings of science practices. Therefore, in the research group the teachers should be given more responsibilities and the research should be guided by the teachers rather than the mentors.

Overall, the teachers who actively engaged in the science practices, had productive discussions with the graduate student mentors and participated the quick lessons that they gave, read the literature for their research, used new techniques and methods, and participated in the research group meetings improved more on the abilities of the science practices compare to the teachers who did not have the opportunity to participate in the practices because of the structure of their projects, had low interest and received most of the information directly from the graduate students. In addition, the support in the research group and the engagement in the science practices are very important to improve teachers' understandings of the science practices. The practices that the teachers do not engage in and the research that is guided primarily by the mentors do not help much the teachers to understand the science practices.

CHAPTER FIVE:

CONCLUSIONS AND IMPLICATIONS

In this chapter, I present conclusions and implications of the study. First, I discuss whether the experiences of the teachers indicated whether they worked as apprentices in their projects. In order to explain that, I used the apprenticeship model developed by Lave and Wenger (1991). Second, I discuss the findings of the teachers' abilities to engage in science practices based on the model for learning by doing research (Feldman, Divoll, & Rogan-Klyve, 2009, 2013). Next, I explain how I grouped the science practices based on the roles of novice researcher, proficient technician, and knowledge producer and discuss what the teachers' roles were at the beginning and at the end of the RET program. I also discuss the teachers' abilities to engage in science practices and how their experiences can be explained based on the communities of practice and epistemic communities by making connections to their roles in the program such as novice researcher, proficient technician, and knowledge producer. I will then discuss the findings of the teachers' understandings of the science practices by making connections to teacher roles (Feldman, Divoll, & Rogan-Klyve, 2009) followed by the sources of different changes in teachers' abilities and understandings of science practices. Finally, I present the implications, limitations and delimitations of the study.

Conclusions

In this section, I present the conclusions of the research questions by discussing the findings of the research.

Apprenticeship

The teachers in the RET program can be divided into three groups in terms of the experiences that they had in their projects. The first group of teachers participated in the projects that included scientific research. Their research topics were the management of nitrogen cycle, provision of clean water, or urban infrastructure improvement. Those teachers worked in the labs or in the field, and they identified a research question, hypothesis or problem, did a literature review, collected and analyzed data, and reported their results. The second group of teachers worked on well drilling for urban infrastructure improvement. They primarily worked on how to drill the wells, but they did not have the opportunity to identify a research question, or collect, analyze, and interpret data. The projects of the teachers in the third group were related to lesson plan development about the nitrogen cycle, access to clean water, and urban water infrastructure improvement. They worked on developing or revising lesson plans that are related to the RET research topics. Those teachers worked in groups, had meetings with the graduate student mentor, prepared new lesson plans, and made revisions on the previous lesson plans. All the teachers in those three groups developed and presented their posters at the end of the program.

The experiences of the teachers who engaged in the scientific research can be explained based on the apprenticeship model because they are aligned with the main characteristics of apprenticeships that were developed by Lave & Wenger (1991). Firstly, the apprentice completes the tasks which are divided into manageable parts by the graduate students and faculty. This helps the apprentice to improve the knowledge and skills required to complete the work (Lave & Wenger, 1991). In the RET program, those teachers worked in research groups and participated in different research projects. The research groups included the professor, graduate and undergraduate students, and the teacher. In most of the groups, the teacher and the graduate student worked more closely during the research process. In those groups, the graduate students had discussions with the teachers and divided the research into different parts for teachers in order to complete it. These parts included the identification of the research problem or question, the design of the research and the experiments, collecting and analyzing the data, communicating the results, and preparation of the poster. For instance, some graduate students provided articles and reports so the teachers learned the nature of their research and what should be investigated. In some groups, the graduate students allowed the teachers to identify the research question themselves. For instance, in the case of Ivette, the graduate student sent her the dropbox folder and asked her to read and identify the research problem that she wanted to investigate. In addition, in those groups the teachers collected and analyzed the data after they had discussions with the graduate students. The teachers then discussed what they found in their research. Similarly, through discussions the graduate students guided the teachers about how to prepare their posters. This suggests the graduate students divided the research into manageable parts for the teachers.

Secondly, the apprentice performs the tasks in a way that is similar to the expert's procedure (Lave & Wenger, 1991). In the apprenticeship model, the novice becomes an expert "through the mechanism of acculturation into the world of the expert" (Brown, Collins, & Duguid, 1989, p. 466). In the RET program, the teachers who engaged in the scientific research completed the tasks in a similar way with the experts because their professors, and especially the graduate students, worked with the teachers and taught and guided them about how to complete specific parts of the research. For instance, the graduate students taught the teachers certain practices, and how to use particular instruments in the lab. For example, they were shown how to use ion and gas chromatographs, design the experiments, collect the data, analyze the data, and prepare the poster. The teachers learned how to complete all of these tasks from the example of the graduate students. This suggests the teachers performed the tasks in a way that is similar to the graduate students' and the professors' procedures.

Thirdly, the learning and practice of the apprentice occur simultaneously because the apprentice learns by practicing the tasks (Lave & Wenger, 1991). In the RET program, the teachers learned how to engage in science practices by actually performing them. The results indicated that one of the most important factors that affected teachers' improvement on the science practices was actually engaging in the science practices. For instance, most of the teachers stated that they learned how to collect and analyze data by actually performing, collecting, and analyzing the data for their research. Similarly, in the post interviews, they stated that they presented their research several times, indicating that helped them to learn orally communicating the results of their research. That means while they practiced those tasks they also learned how to engage in them. Therefore, their learning and practicing occurred simultaneously. Also, they engaged in legitimate peripheral participation in authentic scientific research. Their participation was legitimate because the work that they completed in their research group was important and used for the purposes of the research that was performed by the professor and graduate student. Their participation was peripheral because at the beginning they did not have much experience about engaging in research, but at the end of the program they gained more experience and improved on some of the practices. Thus, in the RET program those teachers were novice researchers at the beginning, but then they learned how to engage in those practices and became more knowledgeable.

The teachers who worked on the well drilling project engaged in a well drilling apprenticeship. They were given tasks about how to drill wells by the graduate student and completed the well drilling tasks in a way similar to experts since they discussed it with the graduate student. This suggests they worked like well drilling apprentices. Also, at the beginning of the program those teachers did not have much experience about how to drill wells, but during the program they performed the task and most likely learned some aspects of well drilling. This suggests their practicing and learning occurred simultaneously. They participated in the activities of well drilling, such as deciding the place of the wells on the field and performing the drilling process. They engaged in legitimate peripheral participation in an authentic well drilling experience. Their participation was legitimate since the wells they drilled were important because they will be used by the professor and graduate student in their research. Also, their participation was peripheral since they were novice and did not have much experience about well drilling at the beginning of the program but most likely learned some aspects of how to drill wells and became more experienced about it at the end. In addition, they read a few reports and watched videos to learn how to drill the wells.

However, their experience was not an authentic research apprenticeship because they did not have the opportunity to gain the experiences of research apprentices. For example, they were not given the opportunity to have or develop a research question or a hypothesis, and they did not design an experiment or collect, analyze or interpret data. This means they did not engage in legitimate peripheral participation in an authentic scientific research. In the program, they read some articles for the project, watched videos to learn how to drill the wells, drilled the wells, and presented their posters. Their posters were more focused on the topic of their project and the classroom connections rather than research because they did not participate in an authentic research process.

The third group of teachers participated in the activities of lesson plan development and revision. Some teachers' purpose was to develop content for a summer camp at a science and technology education center. The other teachers' purpose was to prepare and revise the Urban Stormwater Management curricular unit on Green Space Based Learning (GSBL). Those teachers worked in groups and had meetings with the graduate student mentor. The graduate student gave tasks about lesson planning, and the teachers completed their lesson plans and did the revisions. In the lesson planning group, one teacher was preservice and the others were experienced inservice teachers. They engaged in the activities of lesson planning, such as reviewing the Next Generation Science Standards in order to determine what the teachers were expected to teach and what kind of activities they needed to include in the lesson plans, having discussions with the graduate student about the engineering content that they would include in the lesson plans, and developing and revising lesson plans.

In that group, the preservice teacher engaged in legitimate peripheral participation in an authentic lesson plan development experience. Her participation was legitimate because the lesson plans she developed and revised are important and will be used for the purposes of the research that was done by the professor and graduate student. Also, her participation was peripheral since at the beginning of the program she was a novice in terms of development of lesson plans, and at the end of the program she most likely gained more experience and learned how to prepare lesson plans by engaging in those activities and by interacting with experienced teachers and the graduate student. This suggests the experience that she had in the program was a lesson planning apprenticeship. On the other hand, the expert inservice teachers were legitimate participants in the group, but their participation was not peripheral and they did not work like an apprentice. First of all, their participation was legitimate because the lesson plans they completed in the program were important and will be used for the main purposes of the research that was conducted by the professor and the graduate student. However, their participation was not peripheral because they already had more expertise in lesson planning than the graduate student. This suggests they did not work like apprentices in the group. Although it is possible that the inservice teachers might have learned at least some engineering content knowledge, this research does not provide data whether inservice teachers learned more about engineering content since the purpose of the research is related to teacher understandings of science practices.

In addition, the teachers in the lesson planning group did not have a research apprenticeship since they did not engage in research activities and did not have the experiences of an apprentice who is involved in research. That means they did not engage in legitimate peripheral participation in an authentic scientific research. At the end of the program, they presented their posters, but their posters were more focused on the lesson plan development and classroom connections rather than scientific research because they did not participate in an authentic research process.

Overall, in the RET program there were three types of experiences. The first was the research apprenticeship that provided opportunities for the teachers to work in the labs or field; identify a research question, hypothesis or problem; do a literature review; collect and analyze data; and report their results. Those teachers engaged in legitimate peripheral participation in an authentic scientific research. The second experience was the well drilling apprenticeship that allowed the teachers to work on well drilling for urban infrastructure improvement. They primarily worked on the activities about how to drill the wells. They engaged in legitimate peripheral participation in an authentic well drilling experience. The third was the lesson plan development experience that allowed the teachers to revise and develop lesson plans about the nitrogen cycle, access to clean water, and urban water infrastructure improvement. The preservice teacher engaged in legitimate peripheral participation in an authentic lesson plan development experience and worked like a lesson planning apprentice in the program. She most likely learned how to prepare lesson plans and gained some knowledge about engineering content. The inservice teachers were legitimate participants of the lesson planning group. Their participation was not peripheral, and they were not apprentices since they possessed more experience in lesson planning than the graduate student.

The teachers who involved in the well drilling and lesson plan development did not experience the research apprenticeship since their projects did not include a scientific research component. They did not have the opportunity to identify a research question, or collect, analyze and interpret data. Therefore, they did not engage in legitimate peripheral participation in an authentic scientific research. This suggests the teachers in the research apprenticeship were involved in the process of scientific research, and therefore had a very different apprenticeship experience than the teachers who involved in the well drilling and lesson plan development.

Teachers' Abilities to Engage in Science Practices

In this section, I discuss the findings and provide conclusions about the teachers' abilities to engage in science practices based on the model for learning of doing research (Feldman, Divoll, & Rogan-Klyve, 2009). First, I explain how I grouped the science practices based on the roles of novice researcher, proficient technician, and knowledge producer, and discuss what the teachers' roles were at the beginning and at the end of the RET program. In this section, I focus on the teachers who engaged in the research apprenticeships since they were involved in the scientific research and science practices in the RET program.

Teacher roles as novice researcher, proficient technician and knowledge producer. Feldman, Divoll, and Rogan-Klyve (2009) explain the characteristics of novice researcher, proficient technician, and knowledge producer. Based on their explanations, I prepared Table 24 in order to make connections between the novice researcher, proficient technician, and knowledge producer and what science practices they are able to engage in the process of performing research. My purpose was to find the RET teachers' roles at the beginning and at the end of the program based on their improvement in the science practices in which they were able to engage.

Table 24.
Science practices and proficiencies of novice researcher, proficient technician and knowledge producer

Proficiency	Novice Researcher	Proficient Technician	Knowledge Producer
Methodological Proficiency	Make observations and collect data Orally communicate the results	Make observations and collect data Orally communicate the results Interpret data Understand controls Analyze data Use mathematics and computational thinking Use models Make use of the literature Write scientific research reports	Make observations and collect data Orally communicate the results Interpret data Understand controls Analyze data Use mathematics and computational thinking Use models Make use of the literature Write scientific research reports
Intellectual Proficiency		Think independently* Design experiments*	Think independently Design experiments Understand fundamental concepts Identify a question Formulate a hypothesis Reformulate the hypothesis Relate results to the bigger picture Construct explanations Engaging in arguments

Note. * Some novice researchers engage in those practices although knowledge producers are more able to engage in them

Below, first I explain how I grouped the science practices based on the roles of the participants, and then I present how I located the RET teachers into those roles at the beginning and at the end of the program.

Feldman, Divoll, and Rogan-Klyve (2009) state that novice researchers have very limited research experience or do not have experiences in scientific research. For instance, beginning graduate and undergraduate honors students can be categorized as novice researchers. They possess some aspects of methodological proficiency. I draw the definition of methodological proficiency based on the explanations in Feldman, Divoll, and Rogan-Klyve (2009) article. Methodological proficiency means having the ability of learning specific techniques, using major instruments and protocols, modifying techniques and developing new ones, transferring established techniques to novel situations, exhibiting familiarity with research and research methods, and using published methodologies and innovating new ones. There are different levels of methodological proficiency. For instance, novice researchers have the ability to learn specific techniques and use them to collect data and report the results of the research. They can develop the skills to help the experts in the laboratory, collect data, and orally communicate the results of the research, but they are not expected to formulate a research question, analyze data, create new knowledge, and provide defensible conclusions. At the beginning of the RET program, most of the teachers were novice researchers because they had little or no previous research experience.

Proficient technicians are more methodologically proficient than novice researchers. The methodological proficiency level of proficient technicians allows them to become an expert in the methods that are used in the research; therefore, they exhibit familiarity with research and research methods. For instance, they have the ability to use the proper protocols to collect and store data. They can analyze data by using the major instruments, and therefore they can use mathematics and computational thinking. They can modify techniques and develop new ones, and transfer established techniques to novel situations; therefore, they can develop and use models that are related to the research. They are able to interpret their data, understand the importance of controls, make use of the primary scientific research literature, write a scientific report of the research, and orally communicate the results. Methodological proficiency level of knowledge producers allows them to be experts of research methods. For instance, they can collect and store data by using proper protocols. They can use major instruments; therefore, they are able to analyze data and use mathematics and computational thinking. They are able to make use of the primary scientific research literature and understand the importance of controls and interpret their data. They can develop and use models that are related to the research because they are able to modify and develop new techniques and transfer them to new situations. In addition, they can disseminate their research by writing a scientific report of the research and orally communicate the results. Although proficient technicians are more able to engage in the practices that are related to methodological proficiency, some proficient technicians may be able to engage in some aspects of the intellectual proficiency.

I draw the definition of the intellectual proficiency based on the explanations in the Feldman, Divoll and Rogan-Klyve (2009) article. Intellectual proficiency includes having the ability to be clear about the research, to see and be aware of the purpose of the research; to use published literature as a source for ideas and as a context for current research; to formulate and articulate research questions; to see the data and analysis as a part of the literature of the field; to produce defensible conclusions from the data; to contribute to the knowledge base by presenting the research at conferences; and to produce, disseminate, or defend new knowledge. For instance, some proficient technicians are clear about the purpose of the research and are able to use published literature as a source for ideas. Therefore, they can design their experiments and think independently about their research.

The data analysis of this study indicated that overall teachers' abilities to engage in science practices related to methodological proficiency improved more than the practices related to intellectual proficiency. At the end of the program, they were more able to engage in the practices related to methodological proficiency. This suggests that most of the teachers who engaged in scientific research gained methodological proficiency more than intellectual proficiency; therefore, they left the RET program as proficient technicians.

In addition to the practices of the proficient technicians, knowledge producers are able to identify their research questions and hypothesis and reformulate it, develop new methods, and make contributions to the literature through research as well. They have both methodological and intellectual proficiencies; therefore, they are able to make a significant contribution to the research field. For instance, knowledge producers have the ability to draw defensible conclusions from the data; therefore, they can engage in arguments from evidence and construct explanations about the research. In addition, knowledge producers are aware of the research and the purpose; therefore, they are able to identify the research question, formulate the hypothesis, and reformulate the original hypothesis. They can use published literature as a source for ideas and as a context for current research; therefore, they understand the fundamental concepts of the research. They can produce, disseminate, or defend new knowledge; therefore, they are able to write scientific research reports. They can see the data and analysis as something that would become part of the literature of the field; therefore, they can relate the results of their research to the bigger picture. Those practices suggest that knowledge producers are able to engage in the practices related to intellectual proficiency.

The analysis of the results indicated that the teachers did not demonstrate substantial improvements in the practices related to intellectual proficiency. Therefore, after having the research experience in the RET program, none of the teachers left as a knowledge producer. Although some teachers had some improvements in their abilities of science practices related to the intellectual proficiency, they would still need to have more experiences and improvements on those practices in order to be knowledge producers.

The data analysis of this research indicated that while Ivette's abilities to engage in science practices improved more than other teachers and she gained the knowledge and skills that go beyond being a proficient technician, Ashlynn's abilities to engage in science practices did not improve much and she left the program as novice researcher. Therefore, I explain their cases in this section as well.

Ashlynn was a novice researcher at the beginning of the RET program because the data analysis in chapter 4 indicated that although she had research experience beforehand, her abilities to engage in science practices were very low. Her graduate student ratings for most of the science practices were 2, and for some of them they were 1. In addition, her self-reported assessments were low at the beginning of the program as well. The analysis indicated that after having the research experience she did not have much improvement in the practices related to intellectual proficiency. She had a little improvement on only some of the practices related to methodological proficiency, such as making observations and collecting data and orally communicating the results of research. At the end of the program, she was more able to engage in only some of the practices related to methodological proficiency such as understanding the importance of controls, making observations, and collecting data and orally communicating the results of the research. This suggests she gained some aspects of methodological proficiency but not intellectual proficiency; therefore, she left the program as a novice researcher.

Ivette had very limited research experience before she participated in the RET program, and the data analysis indicated that her abilities to engage in the science practices were low at the beginning of the RET program. The ratings of Ivette and her graduate student for her abilities to engage in science practices were between 2.5 and 3. The data analysis suggests that she was a novice researcher at the beginning of the RET program. The data analysis also indicated that after having the research experience she improved in the science practices related to methodological and intellectual proficiencies. Although there are some practices such as making use of the primary scientific research literature, reformulating the original hypothesis, and writing a scientific report of research that she showed least improvements, data analysis indicated that at the end of the program she was able to engage in the practices related to methodological proficiency and also some practices related to intellectual proficiency. That means at the end of the program, Ivette had moved along the continuum, in some ways gaining some of the knowledge and skills that go beyond being a proficient technician. I will address why her abilities improved more than other teachers later in this chapter.

In short, in the RET program most of the teachers were novice researchers at the beginning because they had little or no previous research experience. The teachers in the research apprenticeship gained more experiences and improved in the science practices related to methodological proficiency; therefore, most of them left the program as proficient technicians. Only one teacher gained both methodological proficiency and some aspects of intellectual proficiency; therefore, she moved along the continuum in some ways, gaining some of the knowledge and skills that go beyond being a proficient technician.

Communities of practice and epistemic communities. In this section, I provide conclusions by discussing teachers' abilities to engage in science practices and how their experiences can be explained based on the communities of practice and epistemic communities by making connections to their roles in the program such as novice researcher, proficient technician, and knowledge producer, and the types of the apprenticeships such as research apprenticeship, well drilling apprenticeship, and lesson plan development apprenticeship.

Feldman, Divoll, & Rogan-Klyve (2013) discuss the experiences of the participants in a research group that has the characteristics of community of practice and epistemic community. I used that model because it allowed me to explain what kind of experiences the teachers had in the RET program, and how their experiences can be grouped as novice researcher, proficient technician, and knowledge producer.

The communities of practice, epistemic communities, and the trajectories of novice researchers, proficient technicians, and knowledge producers are shown in Figure 13 (Feldman, Divoll, & Rogan-Klyve, 2013). The research group is represented by the largest oval. The left side in the largest oval represents the features of the community of practice, and the right side represents the features of the epistemic community. The dashed line means there are no certain boundaries between epistemic community and community of practice. The research group shows the characteristics of both communities of practice and epistemic communities. Participants may have different characteristics and show the characteristics of communities of practice or epistemic communities or both.

Communities of practice have the characteristics of mutual engagement, joint enterprise, and a shared repertoire. The members are connected to each other by a mutual negotiation and engagement (Wenger, 1998). In community of practice, people aim to accomplish and complete a product. In epistemic community, people are mutually engaged in order to create and produce new knowledge. Since the purpose of the epistemic communities is to create knowledge, the members of the community must be able to warrant the new knowledge to convince other people who are not the members of the research group. In short, in the community of practice the main goal is to produce a product, and in the epistemic community the main goal is to create new knowledge (Knorr Cetina, 1999). This suggests while community of practice has methodological proficiency, epistemic community has both methodological and intellectual proficiencies.

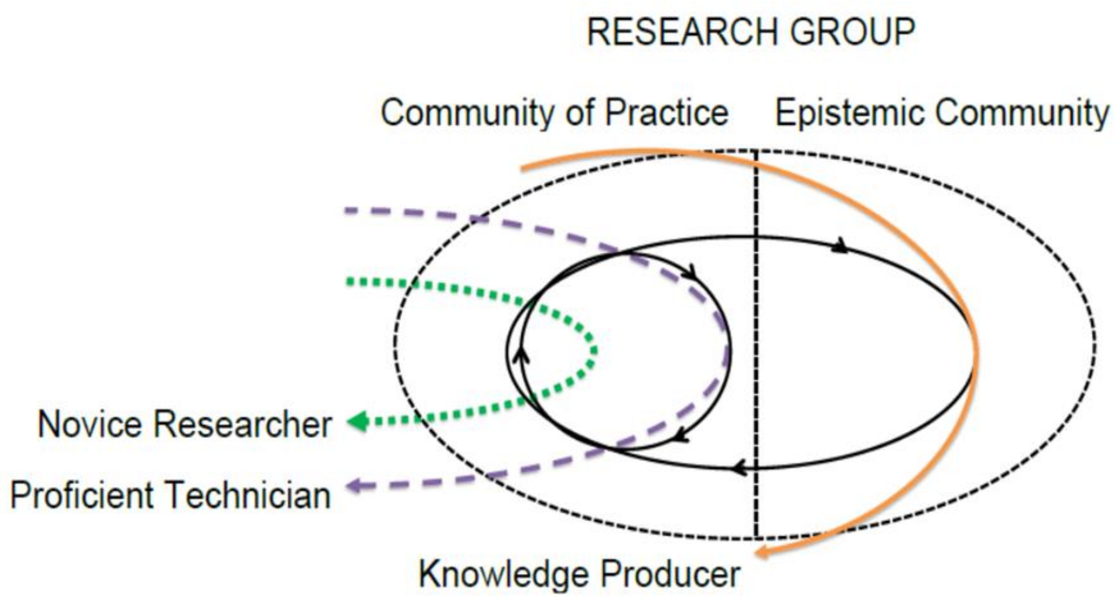

Figure 13. Communities of practice and Epistemic Community (Feldman, Divoll, & Rogan-Klyve, 2013, p.239).

In the RET program, although the research apprenticeship groups showed both the characteristics of community of practice and epistemic communities, most of the participants experienced only community of practice. The possible path of their experience is shown in Figure 14.

The research groups have the characteristics of epistemic communities because they had a shared goal, which was to produce new knowledge based on the results of their research. The professors, graduate students, and the teachers engaged in the research activities such as collecting, analyzing, and interpreting data and helped each other to complete their projects. The teachers' legitimate peripheral participation in the community of practice helped them to improve on the science practices related to methodological proficiency. Therefore, most of them moved from being novice researchers to proficient technicians. The data analysis suggests that the teachers did not have opportunities to experience the epistemic community; therefore, they indicated limited growth of intellectual proficiency. This did not allow them to become knowledge producers.

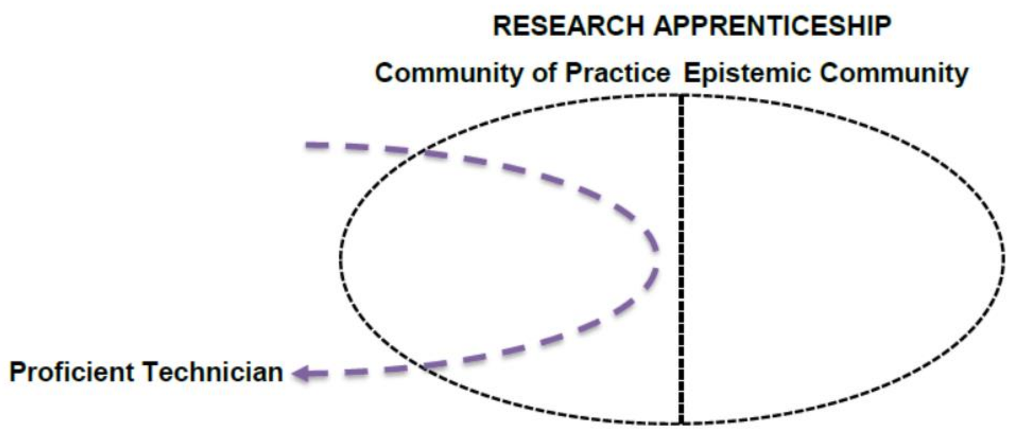

Figure 14. Teachers in the research apprenticeship group

The results indicate that in the RET program some teachers entered the research and left without being a full participant in the group. For instance, Ashlynn's group has the characteristics of both community of practice and epistemic community since their shared goal was to produce new knowledge based on the result of their research, but she experienced it more as a community of practice. She engaged in the research activities with the graduate student, and they helped each other to complete their projects. The data analysis indicated that while Ashlynn gained abilities in collecting data and orally communicating the results of research, she did not gain much improvement in the other science practices. That means her legitimate peripheral participation in the community of practice helped her to gain only some methodological proficiency but not intellectual proficiency. Therefore, she left the group as a novice researcher. A possible path for her experience is shown in Figure 15.

Figure 15. Ashlynn left as novice researcher

Ivette's research group also has the characteristics of both community of practice and epistemic community since the purpose of the group was to produce new knowledge based on their project. In her group, Ivette experienced the community of practice as well as some aspects of the epistemic community. The data analysis suggests that Ivette's legitimate peripheral participation in community of practice and epistemic community helped her to improve on the practices related to methodological proficiency and some practices related to intellectual proficiency. Therefore, she has moved along the continuum in some ways, gaining some of the knowledge and skills that go beyond being a proficient technician. A possible path for her experience is shown in Figure 16. Although she would still need improvements in those practices that are required to be a knowledge producer, compared to the other teachers she improved more on the science practices.

The process leading from engaging in the community of practice and epistemic community to being a novice researcher, proficient technician, and knowledge producer is shown in Figure 17. The figure also shows Ashlynn's experience in community of practice and Ivette's experience in community of practice and epistemic community.

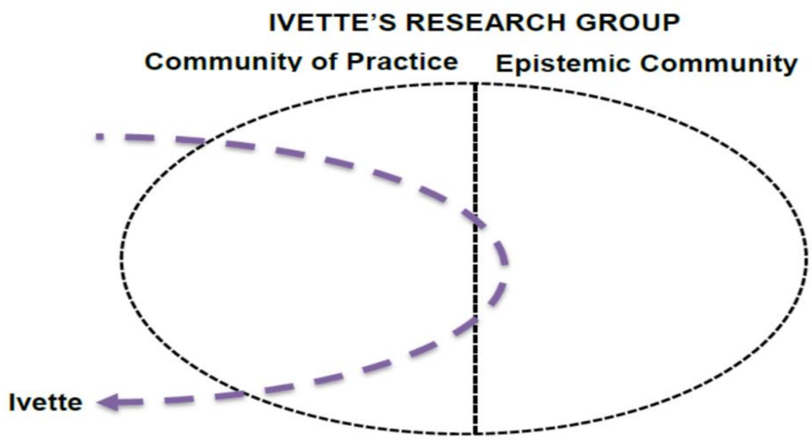

Figure 16. Ivette has moved along the continuum of being a proficient technician

Ivette's research group was the most important factor that helped her to participate in the epistemic community. The data analysis indicated that her research group was tightly organized (Feldman, Divoll, & Rogan-Klyve, 2009). In the tightly organized research groups, the center of action is the laboratory and the interactions between the members are very important. Although the professors play an important role in developing the groups and facilitating interactions among the students, the interactions among the members that take place on a continuing basis are also important (Feldman, Divoll, & Rogan-Klyve, 2009). In Ivette's group, the center of their action was the laboratory because all the graduate students of the same professor and Ivette work together in the same laboratory in order to complete their project. Their professor played an important role in developing the interactions between the graduate student and Ivette.

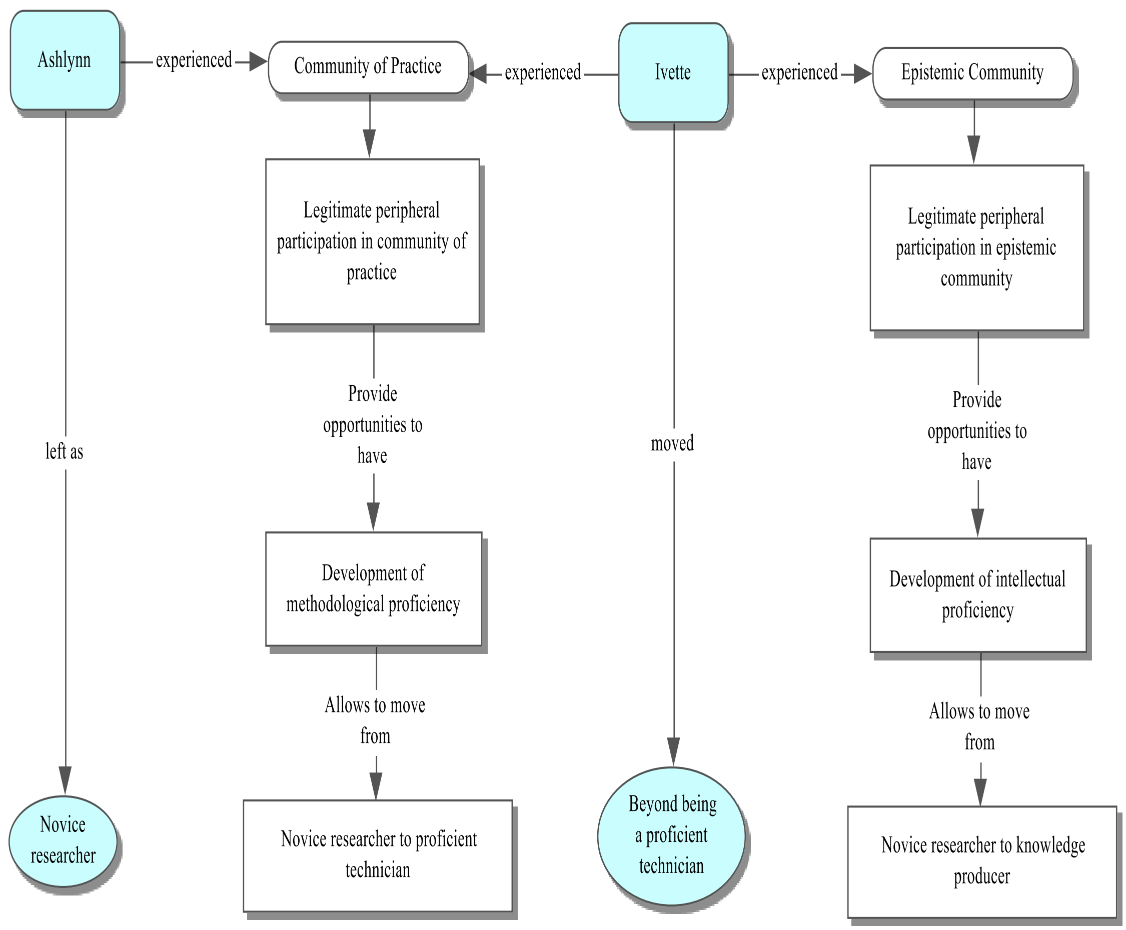

Figure 17. The process from engaging in the community of practice and epistemic community to being a novice researcher, proficient technician and knowledge producer. Connection to Ashlynn's and Ivette's experience in their research groups.

For instance, the professor, the graduate students, and Ivette had weekly big group meetings in which they discussed their research and the students gave presentations about their research. This leads to interactions not only between Ivette and her graduate student but also with the other graduate students, the professor, and the other RET teacher who worked with another graduate student of the same professor. Also, Ivette had discussions about her research with her graduate student mentor on a daily basis. This suggests she had daily small group meetings with the graduate student; therefore, Ivette had opportunities to have more interactions with the graduate student.

Her research group provided opportunities to engage in most of the practices, so she improved on those practices more than the other teachers. For instance, she was asked to identify her research question by reviewing the literature and design the experiments by discussing with the graduate student. She collected her data and got help from the graduate student in the data analysis, which helped her to improve on those practices. She also participated in weekly research group meetings with her professor and the graduate students. Those activities that she engaged in with her research group helped her to gain experiences in the epistemic community.

While Ivette participated in a tightly organized research group, the other teachers engaged in loosely organized groups (Feldman, Divoll, & Rogan-Klyve, 2009). First of all, it was evident that most of the teachers did not have the opportunity to interact with the professors. For instance, when those professors were asked to complete the survey about the teachers they expressed that they did not had sufficient interactions with the teachers to complete the survey. This suggests they did not have tight connections with the teachers. In those groups, the graduate students interacted more with the teachers than the professors did. In addition, the interactions between the other members of the group were very limited. For instance, some professors had more than one graduate student and each graduate student mentored one or more teachers, but they did not have big research group meetings that involved all the graduate students and teachers. Therefore, the teachers did not have the opportunity to engage in big group meetings with the professor and all the graduate students. This suggests the teachers did not have tight connections with the other graduate students and the professor. In addition, the members of the groups did not participate in any social activities. Therefore, they participated in loosely organized rather than tightly organized groups.

The analysis indicated that the experiences of the teachers when they participate in the research groups are very important in terms of the improvement of their abilities to engage in science practices. In general, the teachers who participate in the scientific research projects that allow them to engage in legitimate peripheral participation in community of practice gain the science practices related to methodological proficiency, and therefore become proficient technicians. In the RET programs, the teachers may engage in legitimate peripheral participation in epistemic communities and gain methodological and some aspects of intellectual proficiencies. Therefore, they can move beyond being a proficient technician. In addition, participating in the activities of tightly organized groups provides opportunities to engage in big group meetings, therefore the teachers can have better interactions with the other members of the group and gain more abilities in the science practices. On the other hand, participation in loosely organized research groups does not provide opportunities to have interactions with the other group members, and teachers may gain less experiences and knowledge about the science practices. The research groups and the activities in which the teachers engage in the groups play an important role in providing them the experiences of the epistemic community and improving on the science practices.

Teachers' Understandings of Science Practices

In this section, I discuss and provide conclusions about the teachers' understandings of science practices, as well as the individual cases. Based on the findings of this research, I draw two conclusions about teachers' understandings of science practices. First, the teachers had naive and incomplete understandings of science practices before they participated in the RET program. Second, their understandings are still naïve and incomplete after they participated in the RET program. In this research, the teachers in the well drilling and lesson plan development apprenticeships would not be expected to increase their understandings of science practices since they did not engage in scientific research. On the other hand, the teachers in the research apprenticeship would be expected to improve their understandings of science practices, but the data analysis did not indicate many improvements. Below, I explain these conclusions in more detail. Then, I discuss the conclusions based on teacher roles, community of practice, and epistemic community (Feldman, Divoll, & Rogan-Klyve, 2009, 2013).

Teachers' understandings of science practices before participating in a research experience. The new science education Framework (2012) and NGSS (2013) emphasize that acquiring and engaging in science practices help students to understand development of scientific knowledge and to become critical consumers of science. Since the teachers are responsible to teach science practices in their classrooms, it is important for them to understand what those practices mean. This research indicated that the teachers have naïve understandings of science practices before they participate in a research experiences for teachers program. This is evidenced by the comparison of teachers' explanations in the pre-interview and professors' conceptions of science practices and the explanations in the Framework. Firstly, the pre-interview was analyzed in order to see how teachers explain the science practices and also to identify the themes based on their explanations. Secondly, for each science practice a description was generated based on teachers' explanations and the themes in the interview. The same procedure was followed to find out professors' conceptions of science practices and the explanations in the Framework. Next, the descriptions that were generated in the teachers' pre-interview and professor interview and the Framework were compared in order to find out to what extent the teachers understand the science practices.

In the analysis, it was evident that teachers' understandings of science practices related to methodological and intellectual proficiencies were not aligned with the professors' conceptions and the Framework, and additionally their understandings were naïve and incomplete. First of all, this is evidenced by the fact that teachers' explanations of some practices do not include the important components of science practices. In their explanations, they do not provide information about how those practices can be used during the research. I draw a diagram to show how the conclusion that teachers have naïve understandings before they participated in the program is reached based on the evidences in the pre-interview and the reason for why they have naïve understandings (Figure 18). While professors stressed how the practices are used in research, in general the teachers' answers were more focused on what those practices include. For instance, most of the teachers did not provide information about how the primary literature can be used to identify a research question or hypothesis. Instead, they more focused on the details about what the literature includes.

Most of the teachers' understandings more focused on the idea that the literature includes different sources such as books and articles. Although this explanation is not wrong, it does not include the more important aspects that were identified in the professors' explanations. Similarly, for relating results to the bigger picture practice the teachers did not explain how the results of a research study can contribute to the literature. Their explanations related more to the effect of the research to people and society. This suggests the teachers' understanding of relating results to the bigger picture does not include one of the most important aspects of that practice.

The focus of the teachers on the structure and format of the products that are produced based on the science practices, rather than how or why they are produced, also provides evidence for teachers' naive understandings in the pre-interview.

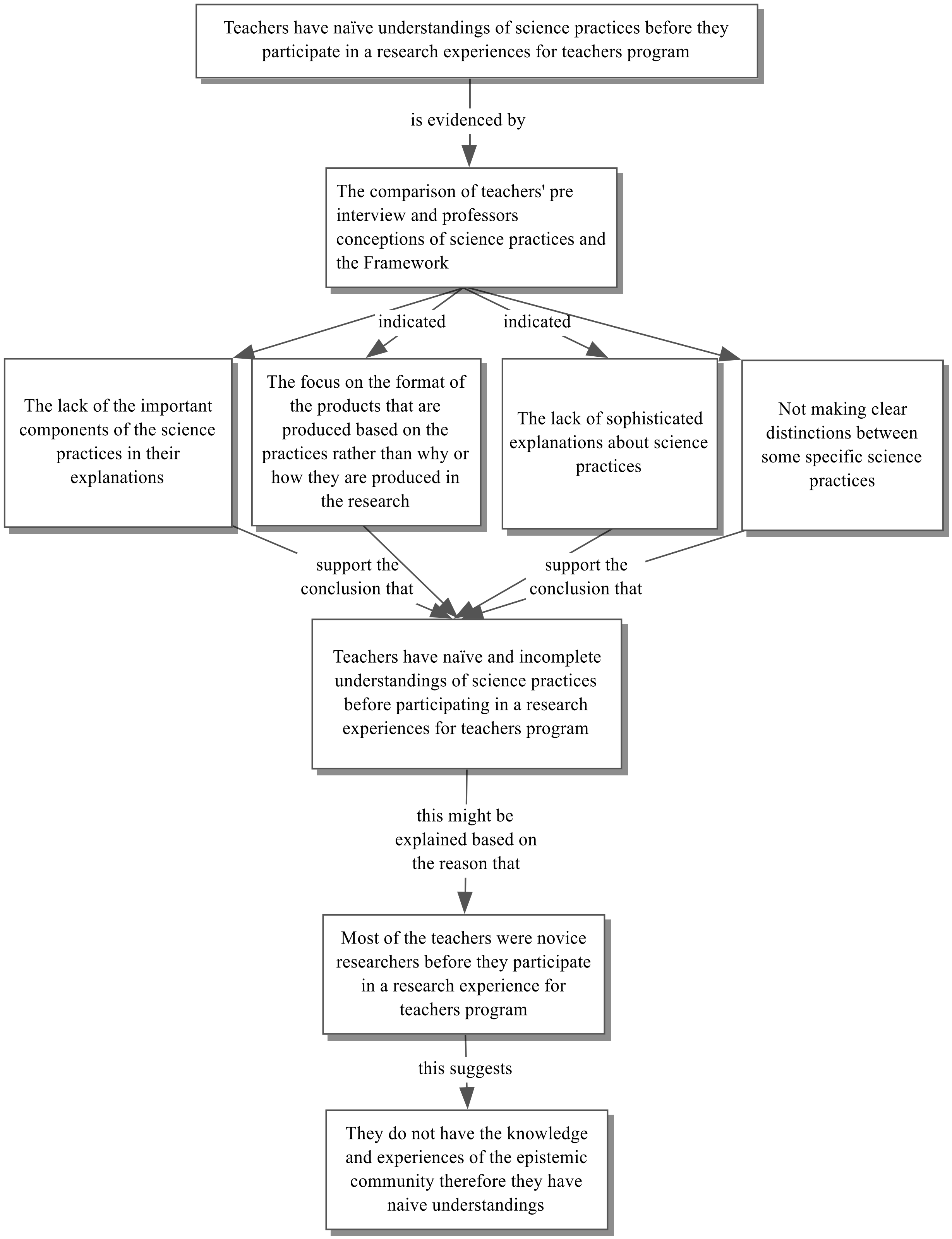

Figure 18. How the conclusion of teachers' naïve understandings before the RET program is supported by the evidences and how they can be explained.

The teachers' understandings of some of the practices related to methodological and intellectual proficiency indicated their focus on the format and structure. For instance, the teachers' understandings of writing a scientific report of research were more related to the design of the report instead of the importance and purpose of them. Their explanations related more to what kind of components such as the introduction, literature review, data analysis, conclusions are included in the design of the reports. On the other hand, the professors put more emphasis on the purpose of the reports and why the reports are written. This suggests the teachers' understandings do not make connections between the reports and the purposes of them. Similarly, the teachers' understandings of formulating a research hypothesis focused more on the structure of the hypothesis rather than how it is identified for the research. While the professors stated that the hypothesis is identified based on the literature, most of the teachers did not state that in their explanations. Instead, they expressed that a hypothesis is an if-then statement, but for the professors it is a testable explanation. This suggests the teachers' understandings of formulating the hypothesis is naïve and incomplete since it does not show the important characteristics of it.

One of the evidences that also shows teachers' naïve understandings before they participated in the RET program is the lack of the information they possess about the differences between the practices. Some of the teachers could not make the distinction between some of the practices related to methodological proficiency. For instance, they did not know how data analysis and data interpretation differ. They thought that both show what the data mean and tell. Similarly, most of the teachers did not provide any information about the differences between data collection and making observations. In general, they provide explanations about making observations but did not explain how they are different. Also, none of the teachers provided information about how control variable and control groups differ. They tended to explain the control group, but they did not give any details about the control variable. Those findings also suggest that the teachers' understandings of the practices are not clear about the differences between some of the practices, and this leads them to have naïve understandings.

The other evidence that demonstrates the teachers' naïve understandings is the lack of sophisticated explanations that some of the science practices are related. This is identified especially in some of the science practices related to intellectual proficiency. For instance, in the new science education Framework, the constructing explanations practice is related to the scientific theories and representations, but none of the teachers made connections to them. Moreover, some of the teachers' explanations about that practice were not scientific. For them, constructing explanations practice means to explain something in daily life. Also, the teachers' understandings of engaging in argument from evidence practice do not make connections to supporting a claim, argumentation, and reasoning as it is explained in the Framework. Their explanations include less sophisticated expressions such discussion, debate, and defending. This suggests teachers' understandings of science practices do not include the expected explanations that are included in the Framework. In the next section, I also explain what might be the reason for teachers' naïve understandings at the beginning of the RET program.

Overall, the findings of this study suggest that teachers have naïve and incomplete understandings of science practices. This is an important conclusion since the new science education Framework and NGSS expect that the students should be able to have both the knowledge and the abilities of science practices. If the teachers are responsible to teach the practices to students then they should have the knowledge of what the science practices mean. This raises the questions of how can we expect teachers to teach the practices in their classrooms at the expected level when they have naive and incomplete understandings, and how the students would have the expected abilities and knowledge of science practices as it is explained in the Framework and NGSS?

Teachers' understandings of science practices after participating in a research experience. This research indicated that participation in the RET program did not improve teachers' understandings of science practices. The research provides several findings regarding teachers' understandings of science practices before and after they participated in an RET program. In looking at the teachers' pre- and post-interviews it was evident that, overall, their understandings of science practices related to methodological and intellectual proficiencies did not indicate improvement from the beginning to the end of the RET program. Although a few teachers' understandings started to be more related to research and science on some practices such as designing an experiment, interpreting data, constructing explanations, making observations and collecting data, orally communicating the results of research, using mathematics and computational thinking, and analyzing numerical data, their overall understandings of those practices were still naïve and incomplete. These findings were identified based on the comparison of pre- and post-interviews. In order to make the comparisons, first the teachers' explanations that were given for each practice were investigated and then the themes were created based on those explanations. After that, the descriptions of each science practice were developed using the teacher explanations and the themes in the pre- and post-interviews. The comparison of those descriptions in the pre- and post-interviews demonstrated that in general teachers did not gain different aspects of the practices in the program.

The analysis also demonstrated that teachers' understandings of science practices were naïve and incomplete at the end of the program. Their naïve understandings of most of the science practices are not aligned with the professors' conceptions and the explanations in the Framework. I draw a diagram that shows how the conclusion that teachers have naïve understandings after they participated in the program is reached based on the evidences in the post-interview and the reason for why they have naïve understandings (Figure 19). As it can be seen in Figures 18 and 19, all the explanations and examples that provide evidences for teachers' naïve understandings at the beginning of the program were identified at the end of the program as well.

One of the explanations that provide evidence for teachers' naïve understandings is the lack of the important components of the science practices in their explanations. For instance, the analysis of this research indicated that at the end of the program (as it is also identified at the beginning), the teachers' understandings of science practices do not include the aspects about how those practices are used or identified in research. While professors' explanations were more focused on how those practices are used in scientific research and why those practices are used during research, teachers' understandings do not include those aspects. Instead, teachers' explanations focused more on what those practices include. This suggests they do not make connections between the science practices and how they are used based on the purposes of a research study. Teachers' understandings of science practices related to methodological and intellectual proficiencies indicated that situation. For instance, most of the teachers did not provide information about how the literature is used to identify a problem situation, research question, and hypothesis. While professors emphasized those points more, the teachers' understandings were more focused on what the literature includes in terms of the kind of resources such as books, articles, and reports. Although this explanation is not wrong since the literature combines different resources, these are less important details compared to what the professors emphasized about that practice.

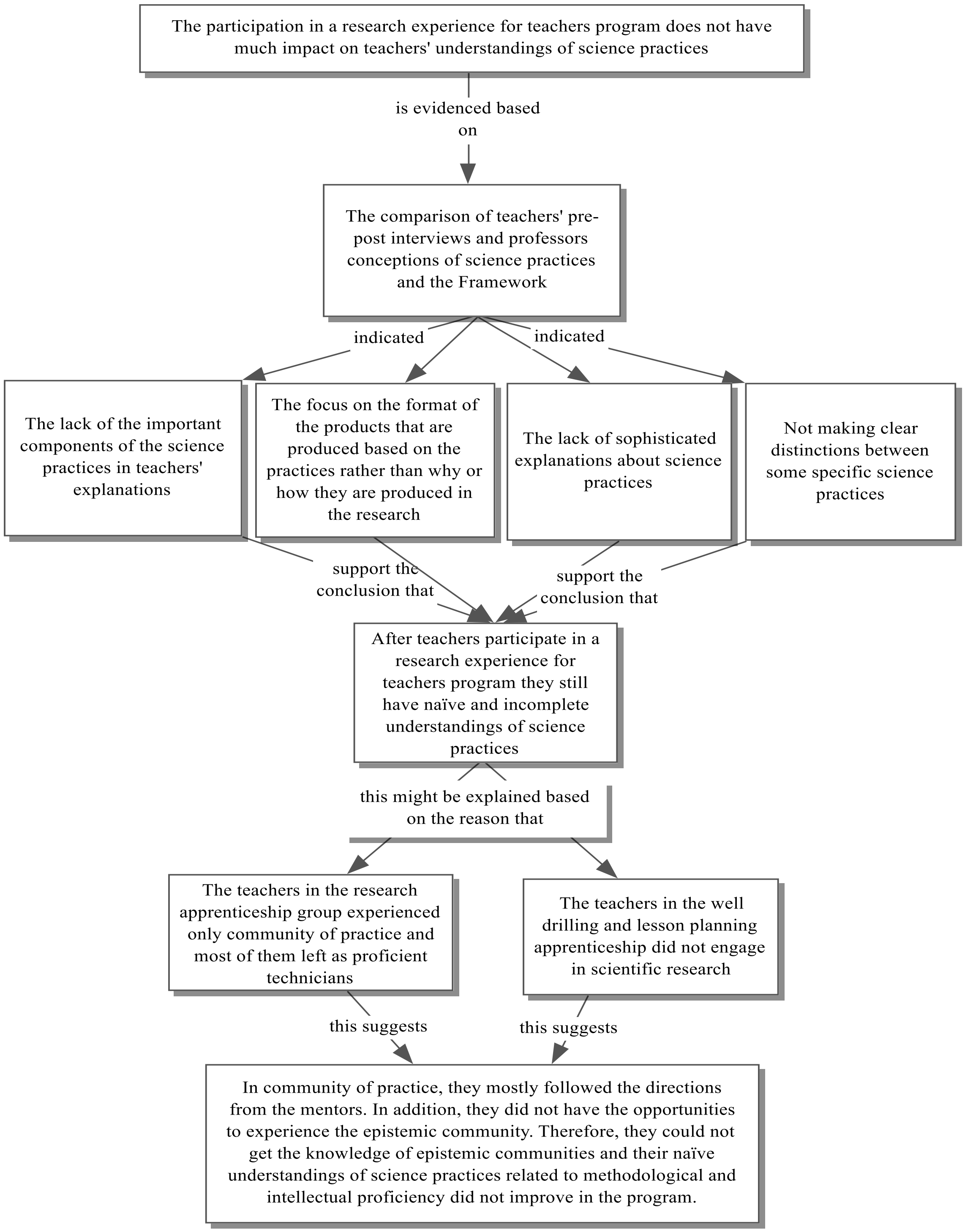

Figure 19. How the conclusion of teachers' naïve understandings after the RET program is supported by the evidences and how they can be explained

Similarly, for the relating results to the bigger picture practice, while professors stressed that this is related to how the findings of the research can contribute to the literature, some teachers see the big picture like a puzzle that connects the results of the other small research studies. This indicates that teachers' understanding of relating results to the bigger picture misses important connections between the bigger picture to how the findings can contribute to it. This suggests their understanding of relating results to the bigger picture is naïve, and they need better explanations to have a complete understanding of it.

Another example that provides evidence for teachers' naïve understandings of science practices at the end of the program, as it is also identified at the beginning, is their focus on the format of the products that are produced based on the practices rather than why or how they are produced based on the practices in a research. The teachers' understandings of some science practices related to methodological and intellectual proficiencies indicated their focus on the structure. For instance, most of the teachers' understandings of research reports focused more on the design and format of the reports, rather than why they are written. Although their explanations about the design of the reports are aligned with the professors, the lack of information they provided about the purpose of the reports indicates most of the teachers have naïve understandings. Similarly, some teachers' explanations about formulating a research hypothesis focused more on the structure of a hypothesis, rather than how a hypothesis is formulated based on the literature. While the professors emphasized that a hypothesis is identified based on the information in the literature, some teachers stated the structure of a hypothesis is an if-then statement. These findings provide strong evidence that the teachers have naïve understandings of science practices.

In addition, it was evident that at the end of the program, as it is also identified at the beginning, some teachers were not able to make clear distinctions between some specific science practices. Some of the teachers could not make the distinctions between some of the practices related to methodological proficiency. For instance, some teachers provided very similar explanations for analyzing data and interpreting data practices. Moreover, they directly stated they were not sure of the differences between those practices. Similarly, most of the teachers did not provide information about the differences between data collection and making observations. Also, their understandings of the importance of control focused more on the control group and they did not explain the control variable. Consequently, they did not explain how the control variable and control group are different. On the other hand, the professors explained how data collection and making observations are different and how the control group and control variable differ from each other. This suggests the teachers' understandings of science practices are not aligned with the professors' and include naïve and incomplete explanations.

Also, the analysis indicated that at the end of the program, as it is also identified at the beginning, the teachers' understandings of some science practices lack the sophisticated explanations that are provided in the new science education Framework and NGSS. This is identified especially in some of the science practices related to intellectual proficiency. For instance, none of the teachers expressed their ideas about constructing explanations by referring to scientific theories, models, and representations as it is stated in the Framework. Similarly, none of the teachers explained their understandings of engaging in arguments from evidence practice by making connections to argumentation, reasoning skills, and justifying a claim like it is explained in the Framework. Instead, their explanations focused more on words like defending and explaining. This suggests they cannot provide more sophisticated information about the practices as it is emphasized in the Framework. In addition, the explanations that they provided for constructing explanations and engaging in argument from evidence practices are not much aligned with the explanations in the Framework.

Ivette's and Ashlyn's understandings of science practices, like the other teachers, were naïve at the beginning of the RET program. In addition, as is identified for the other teachers, the program did not improve their understandings, so after having the research experience both teachers still possessed naïve understandings of science practices related to methodological and intellectual proficiencies. Although the analysis indicated some improvements on Ivette's understandings of only some aspects of a few science practices such as understanding the fundamental concepts of research, constructing explanations, making use of the primary scientific research literature, making observations and collecting data, and interpreting data, her overall understandings of those practices were still naïve and incomplete.

The cases of Ivette and Ashlynn, as well as the data from the other teachers, suggest that participation in a research experiences for teachers program does not have much impact on teachers' understandings of science practices. More importantly, this study uncovered that even if they participated in a research experiences program teachers' still have naïve and incomplete understandings of science practices which are very crucial in the new science education Framework and NGSS.

Below, I provide explanations about what might be the reasons for teachers' naive understandings of science practices at the beginning and at the end of the RET program by making connections to their roles in the program, community of practice, and epistemic communities.

Teacher Roles, Community of Practice, and Epistemic Community

One explanation for why teachers' still have naïve understandings after they participate in a research experience for teachers program is because they did not have opportunities to engage in all science practices. Therefore, they did not have enough experiences and knowledge in order to possess a solid understanding of science practices teachers, which they need to have both the abilities and knowledge of science practices. The new science education Framework states that "acquiring skills in science practices supports a better understanding of how scientific knowledge is produced. Engaging in the practices of science helps students understand how scientific knowledge develops" (NRC, 2012, p.41). This explanation suggests that having the abilities of the science practices helps to understand the procedure of knowledge development. Based on the Framework (NRC, 2012), understanding the science practices includes content, procedural knowledge, as well as epistemic knowledge. Procedural knowledge is understanding the methods and its elements, such as the controls and the procedures. Epistemic knowledge is understanding the meaning of an observation, a hypothesis, an inference, a model, a theory, or a claim; the explanation and argument; and also to know the differences between them. It appears that novice researchers and proficient technicians do not have epistemic knowledge. Feldman, Divoll, and Rogan-Klyve (2009) stated that novice researchers and proficient technicians have the experiences of the community of practice, but they do not have much experience in the knowledge of the epistemic community. This research also supported this finding.

The findings of this research can be explained based on the community of practice and epistemic community as it is provided by Feldman, Divoll, and Rogan-Klyve (2009). The analysis of this research indicated that the teachers were novice researchers at the beginning of the RET program. The research apprenticeship groups have both the characteristics of community of practice and epistemic community, but the teachers mostly experienced the community of practice and most of them left as proficient technicians, while some teachers left as novice researchers. In addition, the teachers in the well drilling and lesson planning apprenticeship did not have the opportunity to engage in scientific research. Although the teachers experienced the community of practice, their understanding of science practices related to methodological proficiency was still naïve and incomplete after the program. In the community of practice, they mostly followed the directions that were given by their mentors during the process of their research. This suggests they followed the directions without learning much about what might be the reasons for using the practices in the ways they did, or what the purposes were of those practices during the research. Therefore, their understandings of the practices related to methodological proficiency did not improve and were still naïve at the end of the program.

The teachers in the RET program did not experience the epistemic community; therefore, they did not get the knowledge of epistemic communities, their naïve understandings did not improve in the program. For instance, Ashlynn was a novice researcher at the beginning and left the research group as a novice researcher. The data analysis indicated that she did not have the opportunity to identify her research question and hypothesis because it was given by the graduate student. Also, she did not design the experiments because she followed the directions on a paper that outlined steps of her experiments. Also, she was not interested in data analysis, and therefore did not have the experience of how to analyze data. In addition, the data analysis indicated that she did not produce a literature review, so she did not have the opportunity to learn the fundamental concepts of her research. Ashlynn’s research was mainly guided by the graduate student; therefore, she did not have the opportunity to engage in thinking independently about her research. These findings suggest she did not have opportunity to experience the epistemic community, so she did not understand the epistemic knowledge and she had naïve understandings of the science practices at the end of the program.

On the other hand, Ivette experienced the epistemic community; her knowledge and skills went beyond being a proficient technician, and she showed some improvements on her understandings more than the other teachers. The data analysis indicated her understandings of science practices related to methodological and intellectual proficiency showed some improvements in the RET program. Although Ivette still had some naive understandings of science practices, engaging in the epistemic community helped her to gain epistemic knowledge and likely gain the understandings of some of the science practices more than the other teachers.

Ivette and Ashlynn participated in the same RET program but had different experiences. The experiences they obtained were very important because those experiences affected their abilities and understandings of the science practices differently. While Ivette participated in a tightly organized research group that helped her to engage in the epistemic community, Ashlynn did not have that experience. Those activities make a big difference in terms of learning how to engage in the practices and have more knowledge about them. Therefore, it is very important for the teachers to have research experiences that are beneficial to them and productive in terms of understanding the science practices.

Overall, the findings of this research suggest that teachers have naive understandings of science practices before they participate in an RET program because they do not have opportunities to learn what those practices mean. The findings also suggest that the teachers still have naive understandings after they participate in an RET program. This is a very important contribution to the literature, in that it is difficult for the teachers to teach those practices in their classrooms if they do not have complete and appropriate understandings of what those practices actually mean. One of the most important reasons for teachers' naïve understandings is that they did not participate in epistemic communities and engage in science practices in the programs, and they mostly followed the directions given by the mentors. This is very important since the teachers are expected to teach those practices in their classrooms. If the RET programs are designed to provide research experiences for teachers, it is important that they provide the teachers opportunities to engage in scientific research. Therefore, the programs should be designed as places to engage the teachers in the science practices and epistemic communities, rather than simply serving as a place for only following the directions that are given by the mentors and participating activities that are not related to doing research.

The Sources of Differences in Teachers' Abilities and Understandings of Science Practices

In this section, I discuss the results and provide conclusions about the sources of differences in teachers' abilities and understandings of science practices.

Legitimate participation is the key component of improving teachers' abilities to engage in science practices. The analysis of the data indicated that the teachers who actively engaged in science practices had productive discussions with the graduate student mentors and participated in the crash courses they gave, read the literature for their research, used new techniques and methods, and participated in the research group meetings improved more on the abilities of the science practices compared to the teachers who did not have the opportunities to participate in the practices because of the structure of their projects, had low interest, and received most of the information directly from the graduate students. The findings suggest that learning how to engage in science practices requires experience with them. The experience helps the teachers to gain the knowledge because their practice and learning occur simultaneously.

One explanation from the data analysis is that the connections between the graduate student and the teacher are very important to improve teachers' abilities to engage in science practices. The teachers learn from the mentor because in the RET program the graduate students helped and taught the teachers how to engage in some of the practices. The data analysis indicated that when the teachers were asked why they think their abilities to engage in the science practices improved they expressed that the graduate students taught them how to engage in some of the practices such as designing the experiment, collecting the data, analyzing the data, using the controls of the research, and preparing their posters. Therefore, it is very important for the teachers to have discussions with the mentors and get their support. For instance, the data analysis also indicated that while Ivette discussed her research with the graduate student and participated in the research group meetings, Ashlynn did not engage in those activities. In addition, Ashlyn was less interested in engaging in the practices. The findings indicated that Ivette improved more than Ashlynn on the abilities of the science practices. These findings suggest that the support and help of the mentors is very crucial to improve teachers' abilities to engage in the science practices.

The research group also plays an important role in improving teachers' understandings of science practices. For instance, the analysis indicated that Ivette's group was tightly organized, and the activities that the group allowed her to engage in helped her to experience the epistemic community and therefore improved her understanding of some of the science practices. On the other hand, Ashlynn's group was loosely organized, her research was mainly guided by the graduate student, and she did not engage in all the practices. Therefore, her understanding did not improve in the program. In addition, the research groups of the other teachers were loosely organized, and their research was guided mainly by the graduate students. The teachers in those groups experienced community of practice and they did not have opportunities to engage in all the science practices, so their understandings did not improve in the RET program. Therefore, the analysis of the data supports the conclusion that teachers who engage in a tightly organized group that allows participating in the activities of epistemic community can improve more than the teachers who only follow the directions of the mentors and do not have sufficient experience related to science practices. Those conclusions are important because if we want teachers to have good abilities and understandings of the science practices we need to provide them with those opportunities. Instead of only providing them the tasks that they need to follow the directions, they should participate in meaningful research experiences that provide them opportunities to have active participation.

Implications

Based on the findings of this study there are important implications for science teacher education and RET programs. I present these implications in this section.

Implications for Science Teacher Education

Recently, the new K-12 science standards were developed and published in order to inform the schools and science teachers regarding the cross-cutting concepts, as well as the science and engineering practices. The authors of the NGSS (2013) expect that students should be able to engage in science practices by grade 12. That means teachers are expected to teach these science practices to their students. The findings of this study have significant implications for science teacher education in order to meet the standards of the NGSS. Taken as a whole, the results of this study indicate that the teachers can engage in science practices to some extent, but they do not understand what it means to engage in science practices. Even experienced teachers have naive and incomplete understandings of science practices. Moreover, although they participated in a research experience, they still have naïve understandings. If this is the situation, the questions that should be asked are: to what extent can we expect the teachers to teach the science practices with their naïve understandings; and to what extent can we expect the students to learn and engage in the practices, as stated in the NGSS, if their teachers have naïve understandings? If we want to meet the standards in the NGSS, first the teachers should be educated in a way that provides them with sufficient understandings and abilities of science practices. Teacher education programs function as the basis for most of the science teachers; therefore, it is important that they provide opportunities for preservice teachers to learn science practices at this early stage. The findings of this study demonstrate teachers' naïve understandings; this suggests current undergraduate programs do not provide sufficient support for teachers to learn what the practices mean. Therefore, it is important that the science method courses and content courses for preservice teachers incorporate science practices within their curriculum. They should place an emphasis on teachers' experience in epistemic communities that allows them to engage in all the practices and focus on learning what each practice means. Since short-term research experiences are not sufficient to learn all the practices, different science methods and content courses can provide more opportunities to the teachers to engage in the practices and experience both the community of practice and epistemic communities for longer durations so that teachers can learn the practices and prepare themselves for their students.

When science method courses and content courses for preservice teachers incorporate science practices, community of practice and epistemic communities would take place in university setting where professors, research assistants, and preservice teachers come together and engage in research that can foster teachers' understandings of science practices. In those epistemic communities, teachers should be given opportunities to identify their own research questions and design their experiments in order to answer their questions. In short, they should be given the opportunity to learn how to become an independent researcher. In addition, explicit instruction in the science practices is also suggested to teach what the practices mean, but the teachers should not be guided to rote memorization of the definitions of the practices. Instead their understandings should be constructed more deeply by scaffolding, engaging in them the epistemic communities and all the practices, having discussions about their research, and showing their weaknesses and strengths about their understandings of the practices. If the teachers graduate having the experience, ability, and knowledge of science practices they would more likely teach their students how to engage in the practices and what they mean, then it is more realistic to expect their students to meet the standards in the NGSS.

Implications for the RET Programs

This study also has implications for the RET programs. Importantly, I believe the study reveals implications regarding the opportunities the teachers are provided when they participate in the RET programs. Firstly, the teachers in the RET programs should be given opportunities to engage in scientific research. This is very important because the literature supports that RET programs provide teachers with opportunities for meaningful research experiences that improve their understandings of scientific research (NRC, 1996; Ononye, Husting, Jackson, Srinivasan, Sorial, Kukreti, 2007), and teachers have the opportunity to reach a sophisticated understanding of how scientists do research. The findings of this research also support those studies. The teachers work as scientists with professors and graduate students and are embedded in the environment of scientific research (Grove, Dixon, Pop, 2009; Ononye et al., 2007). However, some of the teachers in this RET program were not given opportunities to engage in scientific research, either because the professor and the graduate student's research is connected to the lesson plan development and the teachers were only given tasks related to the lesson planning since they have experience with it, or the professor and the graduate student preferred to have the teachers work in well drilling in order to use those wells in their research. This is very important since the program in which they engaged was a research experience program, but some teachers did not get any research experience and left with different experiences. Therefore, if the purpose of the RET programs is to provide teachers with meaningful research experiences, then the teachers should be provided the opportunities to engage in research.

Secondly, this study further shows once the teachers participate in research in the RET programs the legitimate participation and the support they get from the mentors is very important in improving their abilities of engaging in the science practices. The teachers who only engage in methodological aspects of the research are more likely to gain the practices that are required to be novice researchers and proficient technicians. That leads to an important problem, because gaining only methodological aspects of the research does not allow the teachers to improve their understandings of science practices. If they are given opportunities to engage in both communities of practice and epistemic communities, and gain both methodological and intellectual proficiencies, this helps them more to improve their abilities and their understandings of the practices. This is important because the new science education Framework and the NGSS require students to have those practices. If we want the students to learn the science practices, the teachers need to have the abilities and understandings of the science practices since they are responsible for teaching them to the students.

Thirdly, the time that the teachers engage in research is also an important factor that affects teachers' abilities and understandings of science practices. Therefore, it is not realistic to expect teachers to fully participate in both community of practice and epistemic community and thereby gain all the abilities and understandings of science practices in traditional short-term research experiences. It is suggested that placing teachers at least in tightly organized research groups is crucial to provide them with better experiences in the programs. Since the tightly organized research group includes the professor and all the graduate students, the teachers can have more opportunities to interact with them in the small and big group meetings and have discussions with them. Therefore, it is more likely that they will gain more experiences about research than the teachers in the loosely organized research groups. In addition, the role of the mentors is essential in order to support teachers to legitimately engage in the practices. The mentors should use scaffolding instead of directly providing all the information required for the research. Therefore, the RET programs that provide the teachers with the research experience should not be only task oriented or mentor driven.

All the science practices are important, but some of the practices might be considered as more basic than the other practices in order to do science. For instance, identifying a specific question for investigation, making observations and collecting data, analyzing data, and interpreting data can be considered the important fundamental practices to do science. Identifying a specific question for investigation is important because it helps one to be aware of the objective of the study and to know what is missing in the current state of knowledge. Making observations and collecting data is another fundamental practice in doing science because without having data it is not possible to experience the research process. Making observations helps one to realize the problems and to see what went wrong in the research and find solutions to them. The other fundamental and important science practices are analyzing data and interpreting data by relating results to the original hypothesis. The analysis of this research indicated data analysis is one of the practices that had less improvement. Also, the results indicated that some teachers were not able to make clear distinctions between data analysis and interpretation. Those two practices are fundamental in research because data analysis can help them to see the trend in their data and see the power of their results. If the teachers know how to interpret their data they can find out whether their data support the hypothesis and to make decisions about what modifications should be done in the hypothesis or in the research process. Therefore, it is important for them to see the differences between the data analysis and interpretation.

The RET programs should be structured in ways that facilitate the learning of the teachers. For instance, in order to improve teachers' abilities to make observations and collect data the teachers should actually engage in that practice by collecting the data, but the data collection should not be done only by following the directions on a paper, which was seen in some of the cases of this research. The mentors can discuss how the data collection should be done, why it needs to be done in a specific way, and what they should do if an unexpected problem happens. The mentors can demonstrate it for the teachers then guide the teachers during the data collection by scaffolding until the teachers are able to collect the data themselves. The data analysis of this research indicated that the quick lessons about how to analyze data helped the teachers to improve their abilities because it provides the teachers the opportunity to see how the data analysis should be done. In addition, the teachers should do the analysis themselves because merely seeing how it is done does not help them to improve their abilities. They should be given opportunities to analyze their own data by discussing with the mentors. In other words, they should take the responsibility for their research. In order to improve teachers' abilities to interpret data by relating results to the original hypothesis, the teachers should have discussions about the findings of their research with the graduate students and the professors. For instance, if the research groups are tightly organized the teachers will have more opportunity to discuss how to interpret their data and how other people in the group interpret and discuss the results of their research. The teachers can be requested to make a literature review and ask what they are interested in and which research question they would like to find more about. Then, by holding discussions with the mentors the question can be finalized.

Implications for the Training of the Graduate Students in the RET Programs

Since the graduate students play an important role in the RET programs, they need training in teaching the teachers how to engage in science practices. In order to achieve this, the graduate students should be informed explicitly about what the science practices are and the expectations of the new science education Framework (NRC, 2012). This might help them to realize what they need to focus on during their interactions with the teachers. In the training of the graduate students, they should be informed that guiding the teachers is important when they identify their research questions; design experiments; and collect, analyze and interpret data; but they should not provide all this information directly. For instance, in this research some graduate students provided the teachers with a paper that has the steps of the experiments, and the teachers only followed the directions without knowing why they did the things in certain ways. If the teachers only follow the directions then the activities that they are involved in the program might look more like cookbook-type activities, rather than inquiry. Therefore, guiding the teachers in a way that gives them the opportunity to take the responsibility for their research is more efficient. Therefore, the graduate students can be informed about the importance of this step.

In the training of the graduate students, they can be informed that teachers should be provided resources in order to help them to acquire the most fundamental resources about their research, and they should discuss those articles together in order to make sure that the teachers understand them. Those discussions can help the teachers both to have more knowledge about the engineering content and also how the research should be done. The teachers can then be asked to identify the research question that they are interested in. The design of the experiments also can be done with the guidance of the mentors since most of the teachers are novice researchers. Having discussions with the teachers about how things should be done and why they are done in the specific ways is very important as well. In addition, performing a demonstration about how the experiment should be done can help the teachers to understand the process. The graduate students can teach how to analyze the data by giving quick lessons, then the teachers can be asked to do the analysis. After conducting the analysis the graduate students and the teachers should discuss the results, whether they got expected or unexpected results, and if the results are unexpected what they need to modify and which action they need to follow. This can help the teachers to interpret their data in an appropriate way.

Limitations

Although this research was carefully prepared, there were some unavoidable limitations and shortcomings. First of all, in this study not all the teachers participated in research groups and engaged in scientific research. Therefore, those teachers did not have opportunities to have a research experience and engage in science practices. In addition, the research conducted in the RET program lasted only six weeks. The time of the program is important for teachers to improve their abilities and understandings. Long-term research experiences may help the teachers more to increase their abilities and understandings. Therefore, it is preferable to provide longer research experiences to the teachers. Also, there were teachers who did not engage in scientific research.

In this study, the researcher examined one environmental engineering RET program. If the study included more RET programs this might have provided more information about the research results. The other important key element in the research was the sample size. In this study, fifteen teachers participated in this study, but during the data collection there were some problems related to contacting the teachers. For instance, a few teachers did not participate in the post-interview.

In addition, since the assessment of the surveys, interviews, observations, and document analysis were conducted by me, it is unavoidable that a certain degree of subjectivity can be found. Although my personal beliefs, ideas, and experiences may affect the interpretation of the research, efforts were made to improve this by peer examination and member checks. First of all, I utilized member checking with the teachers by showing and discussing both the results and my interpretation of the findings. I also used peer review strategy to decrease the subjectivity. I discussed my research method, data analysis, findings, and interpretation with my advisor, the professors in my committee, and the science educators in different conferences. In addition, I was a scholar in the 2013 Sandra K. Abell Institute which provided me the opportunity to meet in a collaborative environment with other grad students and a wide range of mentors in science education field from all over the world to advance my research design, research methods and communication of research, so I had the opportunity to discuss my research with the professors and graduate students in the Institute.

Delimitations

Participation in this study was delimited to teachers who teach middle and high school science in one of the states of U.S and participated in the environmental engineering RET program at a Research I university. The teachers in other subject areas were not included in the sample because the purpose of the study was to examine science teachers. The study was also delimited to examination of teachers' abilities and understandings of science practices before and after participating an environmental engineering RET program. The study did not examine teachers' abilities and understandings or ideas of other phenomenon which are different than the science practices because the focus of the study was finding out how the program affects the specific practices that are already established by the NRC (2012). The results of the proposed study can be used to understand teachers who (a) teach middle and high school science (b) in the state, and (c) participated in an environmental engineering RET program.

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APPENDICES

Appendix A: Teachers' Understandings of Science Practices Pre-Interview

Part I. Warm up questions:

a. Could you please tell me about yourself including your education, teaching experience, etc.
b. Have you ever participated in an RET program before? Do you have any research experience? If yes, please describe your research. What was your role in this research? How did it affect you?
c. What is your goal about participating in this RET program? What do you want to accomplish in this program?
d. How will this program affect you? Do you think this program will affect your research and teaching skills? Why?
e. What does scientific research mean to you?

Part II. Science skills questions:

I'm going to show you a list of science skills developed by a researcher named Kardash. I am going to ask you what each of these skills means to you. [Show the teacher the list of skills]

1. What does it mean to "understand contemporary concepts in a research area"?
2. What does it mean to "make use of the primary scientific research literature"?
3. What does it mean to "identify a specific question for investigation"?
4. What does it mean to "formulate a research hypothesis based on a specific question"?
5. What does it mean to "design an experiment or theoretical test of the hypothesis"?
6. What does it mean to an "understand the importance of controls"?
7. What does it mean to "make observations and collect data"?
8. What does it mean to "analyze numerical data"?
9. What does it mean to "interpret data by relating results to the original hypothesis"?
10. What does it mean to "reformulate the original hypothesis (as appropriate)"?
11. What does it mean to "relate results to the "bigger picture" in a research area"?
12. What does it mean to "orally communicate the results of research"?
13. What does it mean to "write a scientific report of research"?
14. What does it mean to "think independently about a research area"?

Part III: Science Practices

[Show the teacher the list of science practices.]

1) This is a list of science practices that was developed by the National Research Council and is included in the new national science standards. Please look them over and tell me how you think that are the same or different from the set of skills that we just talked about.

The science practices;

1. Asking questions
2. Developing and using models

3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

2) What does it mean to develop and use models?
3) What does it mean to use mathematics and computational thinking?
4) What does it mean to construct explanations?
5) What does it mean to engage in argument from evidence?

Appendix B: Teachers' Understandings of Science Practices Post-Interview

Part I. Warm up questions:

a. Could you please describe your research?
b. Have you ever participated in an RET program before? How are they different or similar?
c. Please describe your research group. What is your role and others' roles in the research group? How is your interaction with the other group members?
d. Did the RET program affect you? If yes, please explain how it affected your research and teaching abilities.
e. What does scientific research mean to you?

Part II. Science skills questions:

I'm going to show you a list of science skills developed by a researcher named Kardash. I am going to ask you what each of these skills means to you. [Show the teacher the list of skills]

1. What does it mean to "understand contemporary concepts in a research area"?
2. What does it mean to "make use of the primary scientific research literature"?
3. What does it mean to "identify a specific question for investigation"?
4. What does it mean to "formulate a research hypothesis based on a specific question"?
5. What does it mean to "design an experiment or theoretical test of the hypothesis"?
6. What does it mean to an "understand the importance of controls"?
7. What does it mean to "make observations and collect data"?
8. What does it mean to "analyze numerical data"?
9. What does it mean to "interpret data by relating results to the original hypothesis"?
10. What does it mean to "reformulate the original hypothesis (as appropriate)"?
11. What does it mean to "relate results to the "bigger picture" in a research area"?
12. What does it mean to "orally communicate the results of research"?
13. What does it mean to "write a scientific report of research"?
14. What does it mean to "think independently about a research area"?

Part III: Science Practices

[Show the teacher the list of science practices.]

1) This is a list of science practices that was developed by the National Research Council and is included in the new national science standards. Please look them over and tell me how you think that are the same or different from the set of skills that we just talked about.

The science practices;

1. Asking questions
2. Developing and using models

3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

2) What does it mean to develop and use models?
3) What does it mean to use mathematics and computational thinking?
4) What does it mean to construct explanations?
5) What does it mean to engage in argument from evidence?

Appendix C: RET Teachers' Abilities Engaging in Science Practices Pre-Survey

This survey consists of a set of questions about the skills needed to engage in scientific research. Please respond according to your current skill level AT THE BEGINNING of the summer RET program.

We would greatly appreciate it if you would take the time to answer all the questions carefully.

Thank you for your help!

Name:

During this summer you will be working with engineering faculty and graduate students who are studying issues related to the management of the nitrogen cycle, provision of clean water, and urban infrastructure improvement (RET research areas).

Each of the following questions is asked twice -- once in relation to the subject that you teach and once related to the RET research areas listed above. In the following questions I'd like for you to answer them as if you are doing research related to the RET research areas.

Choose one of the following for each question:

Not at all
Very little
Somewhat
Quite a bit
A great deal.

1. To what extent do you think you are able to understand fundamental engineering and science concepts related to the management of the nitrogen cycle, provision of clean water, or urban infrastructure improvement (RET research areas)?

a. Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

2. To what extent are you able to make use of the primary scientific research literature in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

3. To what extent are you able to identify a specific question for investigation in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

4. To what extent are you able to formulate a research hypothesis based on a specific question in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

5. To what extent are you able to design an experiment or theoretical test of the hypothesis in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

6. To what extent are you able to understand the importance of "controls" in research related to one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

7. To what extent are you able to make observations and collect data in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

8. To what extent are you able to analyze numerical data in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

9. To what extent are you able to interpret data by relating results to the original hypothesis in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

10. To what extent are you able to reformulate the original hypothesis (as appropriate) in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

11. To what extent are you able to relate research results to the "bigger picture" in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

12. To what extent are you able to orally communicate the results of research in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

13. To what extent are you able to write a scientific report in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

14. To what extent are you able to think independently in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

15. To what extent are you able to develop and use models in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

16. To what extent are you able to use mathematics and computational thinking in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

17. To what extent are you able to constructing explanations in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

18. To what extent are you able to engage in argument from evidence in one of the RET research areas listed above?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

Appendix D: RET Teachers' Abilities Engaging in Science Practices Mid-Survey

This survey consists of a set of questions about the skills needed to engage in scientific research. Each question is asked twice -- the first time please respond according to your current skill level and the second time according to your skill as you remember it when you began the program.

We would greatly appreciate it if you would take the time to answer all the questions carefully.

Thank you for your help!

Name:

The following questions ask about your ability to engage in scientific research. Choose one of the following for each question:

Not at all
Very little
Somewhat
Quite a bit
A great deal.

1. a) To what extent do you think you are able to understand fundamental engineering and science concepts related to the management of the nitrogen cycle, provision of clean water, or urban infrastructure improvement (RET research areas) AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

1. b) To what extent do you think you were to understand fundamental engineering and science concepts in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

2. a) To what extent do you think you are able to make use of the primary scientific research literature one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

2. b) To what extent do you think you were able to make use of the primary scientific research literature in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

3. a) To what extent do you now think you are able to identify a specific question for investigation in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

3. b) To what extent do you now think you were able to identify a specific question for investigation in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

4. a) To what extent do you now think you are able to formulate a research hypothesis based on a specific question one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

4. b) To what extent do you now think you were able to formulate a research hypothesis based on a specific question one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

5. a) To what extent do you now think you are able to design an experiment or theoretical test of the hypothesis one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

5. b) To what extent do you now think you were able to design an experiment or theoretical test of the hypothesis one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

6. a) To what extent do you now think you are able to understand the importance of "controls" in research in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

6. b) To what extent do you now think you were able to understand the importance of "controls" in research in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

7. a) To what extent do you now think you are able to make observations and collect data AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

7. b) To what extent do you now think you were able to make observations and collect data in one of the RET research areas listed above AT THE BEGINNING of the summer program?

8. a) To what extent do you now think you are able to analyze numerical data AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

8. b) To what extent do you now think you were able to analyze numerical data in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

9. a) To what extent do you now think you are able to interpret data by relating results to the original hypothesis in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

9. b) To what extent do you now think you were able to interpret data by relating results to the original hypothesis in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

10. a) To what extent do you now think you are able to reformulate the original hypothesis (as appropriate) in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

10. b) To what extent do you now think you were able to reformulate the original hypothesis (as appropriate) in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

11. a) To what extent do you now think you are able to relate results to the "bigger picture" in your research area in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

11. b) To what extent do you now think you were able to relate results to the "bigger picture" in your research area in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

12. a) To what extent do you now think you are able to orally communicate the results of your research in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

12. b) To what extent do you now think you were able to orally communicate the results of your research in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

13. a) To what extent do you now think you are able to write a scientific report of your research in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

13. b) To what extent do you now think you were able to write a scientific report of your research in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

14. a) To what extent do you now think you are able to think independently about your research area in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

14. b) To what extent do you now think you were able to think independently about your research area in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

15. a) To what extent do you now think you are able to develop and use models in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

15. b) To what extent do you now think you were able to develop and use models in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

16. a) To what extent do you now think you are able use mathematics and computational thinking in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

16. b) To what extent do you now think you were able use mathematics and computational thinking in one of the RET research areas listed above AT THE BEGINNING?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

17. a) To what extent do you now think you are able to construct explanations in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

17. b) To what extent do you now think you were able to construct explanations in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

18. a) To what extent do you now think you are able to engage in argument from evidence in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

18. b) To what extent do you now think you were able to engage in argument from evidence in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

Appendix E: RET Teachers' Abilities Engaging in Science Practices Post-Survey

This survey consists of a set of questions about the skills needed to engage in scientific research. Please respond according to your current skill level AT THE END of the summer RET program.

We would greatly appreciate it if you would take the time to answer all the questions carefully.

Thank you for your help!

Name:

The following questions ask about your ability to engage in scientific research. Choose one of the following for each question:

Not at all
Very little
Somewhat
Quite a bit
A great deal.

1. a) To what extent do you think you are able to understand fundamental engineering and science concepts in one of the RET research areas (the management of the nitrogen cycle, provision of clean water, or urban infrastructure improvement NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

1. b) If your understanding improved this summer, please name one of those concepts and tell how you gained that understanding.

If your understanding did not improve, please suggest a reason why not.

2. a) To what extent do you think you are able to make use of the primary scientific research literature in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

2. b) If your ability to make use of the literature improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

3. a) To what extent do you now think you are able to identify a specific question for investigation in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

3. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

4. a) To what extent do you now think you are able to formulate a research hypothesis based on a specific question in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

4. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

5. a) To what extent do you now think you are able to design an experiment or theoretical test of the hypothesis in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

5. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

5. c) Have you designed an experiment or theoretical test of your hypothesis in 4c above?

a) Yes b) No

If yes, please describe it.

6. a) To what extent do you now think you are able to understand the importance of "controls" in research in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

6. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

7. a) To what extent do you now think you are able to make observations and collect data in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

7. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

8. a) To what extent do you now think you are able to analyze numerical data in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

8. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

9. a) To what extent do you now think you are able to interpret data by relating results to the original hypothesis in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

9. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

10. a) To what extent do you now think you are able to reformulate the original hypothesis (as appropriate) in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

10. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

11. a) To what extent do you now think you are able to relate results to the "bigger picture" in in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

11. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

12. a) To what extent do you now think you are able to orally communicate the results of your research in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

12. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

13. a) To what extent do you now think you are able to write a scientific report of your research in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

13. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

14. a) To what extent do you now think you are able to think independently in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

14. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not..

15. a) To what extent do you now think you are able to develop and use models in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

15. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

16. a) To what extent do you now think you are able to use mathematics and computational thinking in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

16. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

17. a) To what extent do you now think you are able to construct explanations in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

17. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

18. a) To what extent do you now think you are able to engage in argument from evidence in one of the RET research areas listed above NOW THAT YOU ARE AT THE END of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

18. b) If your ability to do so improved this summer, please tell how you gained that ability.

If your ability did not improve, please suggest a reason why not.

Appendix F: Faculty/Graduate Student Perceptions: RET Teachers' Abilities Engaging in Science Practices Survey

This survey consists of a set of questions about the science practices and skills needed to engage in scientific research.

Each question is asked twice -- the first time please respond according to the current skill level of the teacher working with you and the second time according to his/her skill as you remember it when he/she began the program. Please answer the questions based on the teacher's skill/practice related to the one of the RET research areas (management of the nitrogen cycle, provision of clean water, or urban infrastructure improvement).

If you have more than one teacher working with you, please fill out one form for each of them.

We would greatly appreciate it if you would take the time to answer all the questions carefully. The results of the survey will be used to improve the program and for reports about it to the National Science Foundation.

Thank you for your help!

The following questions ask about your ability to engage in scientific research. Choose one of the following for each question:

Not at all
Very little
Somewhat
Quite a bit
A great deal.

1. Your Name:
2. Teacher's Name:
3. I have had sufficient interactions with the teacher to complete the survey.

a) Yes b) No

If you answered "No" to the previous question, there is no need to complete the survey. Simply close the page on your browser.

1. a) To what extent do you think the teacher is able to understand fundamental engineering and science concepts related to the management of the nitrogen cycle, provision of clean water, or urban infrastructure improvement (RET research areas) AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

1. b) To what extent do you think the teacher was able to understand fundamental engineering and science concepts in one of the RET research areas listed above AT THE BEGINNING of the summer program?

b) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

2. a) To what extent do you think the teacher is able to make use of the primary scientific research literature in in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

2. b) To what extent do you think the teacher was able to make use of the primary scientific research literature in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

3. a) To what extent do you now think the teacher is able to identify a specific question for investigation in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

3. b) To what extent do you now think the teacher was able to identify a specific question for investigation in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

4. a) To what extent do you now think the teacher is able to formulate a research hypothesis based on a specific question in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

4. b) To what extent do you now think the teacher was able to formulate a research hypothesis based on a specific question in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

5. a) To what extent do you now think the teacher is able to design an experiment or theoretical test of the hypothesis in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

5. b) To what extent do you now think the teacher was able to design an experiment or theoretical test of the hypothesis in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

6. a) To what extent do you now think the teacher is able to understand the importance of "controls" in research in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

6. b) To what extent do you now think the teacher was able to understand the importance of "controls" in research in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

7. a) To what extent do you now think the teacher is able to make observations and collect data in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

7. b) To what extent do you now think the teacher was able to make observations and collect data in one of the RET research areas listed above AT THE BEGINNING of the summer program?

8. a) To what extent do you now think the teacher is able to analyze numerical data in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

8. b) To what extent do you now think the teacher was able to analyze numerical data in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

9. a) To what extent do you now think the teacher is able to interpret data by relating results to the original hypothesis in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

9. b) To what extent do you now think the teacher was able to interpret data by relating results to the original hypothesis in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

10. a) To what extent do you now think the teacher is able to reformulate the original hypothesis (as appropriate) in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

10. b) To what extent do you now think the teacher was able to reformulate the original hypothesis (as appropriate) in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

11. a) To what extent do you now think the teacher is able to relate results to the “bigger picture” in your research area in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

11. b) To what extent do you now think the teacher was able to relate results to the “bigger picture” in your research area in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

12. a) To what extent do you now think the teacher is able to orally communicate the results of your research in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

12. b) To what extent do you now think the teacher was able to orally communicate the results of your research in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

13. a) To what extent do you now think the teacher able to write a scientific report of your research in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

13. b) To what extent do you now think the teacher was able to write a scientific report of your research in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

14. a) To what extent do you now think the teacher able to think independently about your research area in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

14. b) To what extent do you now think the teacher was able to think independently about your research area in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

15. a) To what extent do you now think the teacher able to develop and use models in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

15. b) To what extent do you now think the teacher was able to develop and use models in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

16. a) To what extent do you now think the teacher able to use mathematics and computational thinking in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

16. b) To what extent do you now think the teacher was able to use mathematics and computational thinking in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

17. a) To what extent do you now think the teacher able construct explanations in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

17. b) To what extent do you now think the teacher was able to construct explanations in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

18. a) To what extent do you now think the teacher able to engage in argument from evidence in one of the RET research areas listed above AT THIS TIME?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

18. b) To what extent do you now think the teacher was able to engage in argument from evidence in one of the RET research areas listed above AT THE BEGINNING of the summer program?

a) Not at all b) Very little c) Somewhat d) Quite a bit e) A great deal

Appendix G: Graduate Student Perceptions: RET Teachers' Abilities Engaging in Science Practices Interview

Part I. Warm up questions:

a. Could you please describe your research project?
b. Please describe you research group. What is (teacher's name)'s role in the research group.
c. Do you think that the RET program affect him/her? If yes how and why?
d. What did the teacher accomplish by participating in the RET program?

Part II: Perceptions of changes in the teacher's ability.

1. I am going to show you some data that comes from the survey that you filled out about [teacher's name]. I would like to know how you would explain the difference between your ratings of the teacher. Why do you think the teacher's ability changed/stayed the same from the beginning to the end of the summer? [Probe about each skill or practice, especially ones with large differences or no differences.]

2. One of the reasons we think that the teacher's change in their self-assessment of their science practice is due to the change in their understandings of what they meant about this science practice during the summer. Because as they participate in research they gained better understandings of what this science practice means. What do you think of this hypothesis? Can you think anything from the summer that disconfirms this hypothesis?

Teacher Name: ____________________________
Faculty/Grad Student Name: ________________________

Item	Beginning	End
Understand fundamental engineering and science concepts		
Make use of the primary scientific research literature		
Identify a specific question for investigation		
Formulate a research hypothesis based on a specific question		
Design an experiment or theoretical test of the hypothesis		
Understand the importance of “controls” in research		
Make observations and collect data		
Analyze numerical data		
Interpret data by relating results to the original hypothesis		
Reformulate the original hypothesis		
Relate results to the “bigger picture”		
Orally communicate the results		
Write a scientific report		
Think independently about his/her research area		
Asking questions		
Developing and using models		
Planning and carrying out investigations		
Analyzing and interpreting data		
Using mathematics and computational thinking		
Constructing explanations		
Engaging in argument from evidence		
Obtaining, evaluating, and communicating information		

Appendix H: RET Teacher Observation Protocol

Science Practice	What is Teacher doing about this Science Practice?	Researchers' reflective notes
Understand fundamental engineering and science concepts		
Make use of the primary scientific research literature		
Identify a specific question for investigation		
Formulate a research hypothesis based on a specific question		
Design an experiment or theoretical test of the hypothesis		
Understand the importance of "controls" in research		
Make observations and collect data		
Analyze numerical data		
Interpret data by relating results to the original hypothesis		
Reformulate the original hypothesis		
Relate results to the "bigger picture"		
Orally communicate the results		
Write a scientific report		
Think independently about his/her research area		

Appendix I: Sources of Different Changes in RET Teachers' Understandings of Science Practices Interview

Based on the data that were collected from the interviews, surveys and observations we found teachers' understandings of science practices before and after they participated in the RET program.

1. The results indicated that your understanding of 'understand fundamental engineering and science concepts in your research area' improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of 'understand fundamental engineering and science concepts in your research area' is higher/lower than some teachers' change in this practice. How do you explain that? What might be the reasons for that?

2. The results indicated that your understanding of 'make use of the primary scientific research literature in your research area' improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of 'understand 'make use of the primary scientific research literature in your research area' is higher/lower than some teachers' change in this practice. How do you explain that? What might be the reasons for that?

3. The results indicated that your understanding of 'identify a specific question for investigation in your research area' improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of 'identify a specific question for investigation in your research area' is higher/lower than some teachers' change in this practice. How do you explain that? What might be the reasons for that?

4. The results indicated that your understanding of 'formulate a research hypothesis based on a specific question' improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of 'formulate a research hypothesis based on a specific question' is higher/lower than some teachers' change in this practice. How do you explain that? What might be the reasons for that?

5. The results indicated that your understanding of 'design an experiment or theoretical test of the hypothesis' improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of 'design an experiment or theoretical test of the hypothesis' is higher/lower than some teachers' change in this practice. How do you explain that? What might be the reasons for that?

6. The results indicated that your understanding ‘make observations and collect data’ improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of ‘make observations and collect data’ is higher/lower than some teachers’ change in this practice. How do you explain that? What might be the reasons for that?

7. The results indicated that your understanding of ‘understand the importance of “controls” in research’ improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of ‘understand the importance of “controls” in research’ is higher/lower than some teachers’ change in this practice. How do you explain that? What might be the reasons for that?

8. The results indicated that your understanding of ‘analyze numerical data’ improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of ‘analyze numerical data’ is higher/lower than some teachers’ change in this practice. How do you explain that? What might be the reasons for that?

9. The results indicated that your understanding of ‘interpret data by relating results to the original hypothesis’ improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of ‘interpret data by relating results to the original hypothesis’ is higher/lower than the other teachers’ change in this practice. How do you explain that? What might be the reasons for that?

10. The results indicated that your understanding of ‘reformulate the original hypothesis’ improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of ‘reformulate the original hypothesis’ is higher/lower than some teachers’ change in this practice. How do you explain that? What might be the reasons for that?

11. The results indicated that your understanding of ‘relate results to the “bigger picture’’ in your research area improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of ‘relate results to the “bigger picture’ in your research area is higher/lower than some teachers’ change in this practice. How do you explain that? What might be the reasons for that?

12. The results indicated that your understanding of ‘orally communicate the results of your research’ improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of ‘orally communicate the results of your research is higher/lower than some teachers’ change in this practice. How do you explain that? What might be the reasons for that?

13. The results indicated that your understanding of ‘write a scientific report of your research’ improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of ‘write a scientific report of your research’ is higher/lower than some teachers’ change in this practice. How do you explain that? What might be the reasons for that?

14. The results indicated that your understanding of ‘think independently about in your research area’ improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of ‘think independently about your research area’ is higher/lower than some teachers’ change in this practice. How do you explain that? What might be the reasons for that?

15. The results indicated that your understanding of ‘develop and use models’ improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of ‘develop and use models” is higher/lower than some teachers’ change in this practice. How do you explain that? What might be the reasons for that?

16. The results indicated that your understanding of ‘use mathematics and computational thinking’ improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of ‘use mathematics and computational thinking” is higher/lower than some teachers’ change in this practice. How do you explain that? What might be the reasons for that?

17. The results indicated that your understanding of ‘construct explanations’ improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of ‘construct explanations’ is higher/lower than some teachers’ change in this practice. How do you explain that? What might be the reasons for that?

18. The results indicated that your understanding of ‘engage in argument from evidence” improved/stayed same. Why do you think your understanding improved/stayed same?

The change in your understanding of ‘engage in argument from evidence is higher/lower than some teachers’ change in this practice. How do you explain that? What might be the reasons for that?

Appendix J: Poster Presentation Rubric

Criteria	4	3	2	1
Make use of the primary scientific research literature	The poster includes relevant literature and connections are made with the research	The poster includes the relevant literature but needs more information about how they are connected to the research	The poster includes the relevant literature but no connection is made.	The poster has very little or no relevant literature.
Identify a specific question for investigation	The poster includes a clear specific question about the research	The poster includes a specific question but it needs revising	The poster includes a research question but it is not well supported	The poster include inappropriate or no research question about the research
Formulate a research hypothesis based on a specific question	The poster includes a logical hypothesis about the research and it stated clearly	The poster includes a questionable hypothesis about the research	The poster includes a questionable hypothesis and it is not well supported	The poster has inappropriate or no hypothesis about the research
Design an experiment or theoretical test of the hypothesis	The poster includes enough and clear detail about design of the experiment	The poster includes detail about design of the experiment but it needs more information	The poster includes information about the design of the experiment but it is not relevant with the research question/hypothesis	The poster does not include information about the design of the experiment
Understand the importance of “controls” in research	The poster includes clear details about the controls of the research	The poster includes information about the controls of the research but more controls were added	The poster includes information about the controls of the research but some of the controls were lacking	The poster include irrelevant or no controls of the research
Make observations and collect data	The poster includes clear details about	The poster includes information about the	The poster includes information about the	The poster include little or no information about

	the data collection methods	data collection methods but needs more detail	data collection methods but they are irrelevant with the research question/hypothesis	data collection methods
Analyze numerical data	The poster includes clear details about the data analysis	The poster includes information about the data analysis but needs more detail	The poster includes information about the data analysis but it is irrelevant with the research question/hypothesis	The poster include little or no information about data collection methods
Interpret data by relating results to the original hypothesis	The poster includes clear and enough details about the data interpretation	The poster includes data interpretation but significant information is lacking	The poster includes data interpretation but it is irrelevant with the research question/hypothesis	The poster includes little or no data interpretation
Reformulate the original hypothesis	The poster includes a logical reformulated hypothesis about the research and it stated clearly	The poster includes a questionable reformulated hypothesis about the research	The poster includes a questionable reformulated hypothesis and it is not well supported	The poster has inappropriate or no reformulated hypothesis about the research
Relate results to the "bigger picture"	The poster includes a clear information about how the results are related to the bigger picture	The poster includes information about how the results are related to the bigger picture but lacking significant points	The poster relates results to the bigger picture but it shows an irrelevant relation	The poster includes little or no information about relating results to the bigger picture
Orally communicate the results	The presentation includes all expected components and it was clear and well	The presentation includes some of the expected components and it was clear and well	The presentation includes some of the expected components but it was not clear and	The presentation includes some of the expected components but it was very

	organized	organized	well organized	confusing
Write a scientific report	The poster includes all expected components and well organized	The poster includes all expected components but it is not well organized	The poster includes some of the expected components but not clear and well organized	The poster lacks most of the expected components and it is not clear and well organized
Think independently about his/her research area	The teacher shows the ability to think independently by making sense of the results, answering higher order questions and defend their conclusions	The teacher shows some of the ability to think independently by explain the results, answering questions and explain their conclusions	The teacher shows some of the ability to think independently by explain the results, answering questions and explain their conclusions but the explanations are confusing and incomplete	The teacher does not show the ability to think independently
Understand fundamental engineering and science concepts	The teacher show the ability to understand fundamental engineering and science concepts by explain them clearly	The teacher show some of the ability to understand fundamental engineering and science concepts by explain them clearly	The teacher show some of the ability to understand fundamental engineering and science concepts by explain them but it is not clear and confusing	The teacher does not show the ability to understand fundamental engineering and science concepts by explain them clearly

Appendix K: Professors' Conceptions of Science Practices Interview

Part I. Science skills questions:

I'm going to show you a list of science skills developed by a researcher named Kardash. I am going to ask you what each of these skills means to you. [Show the professor the list of skills]

1. What does it mean to "understand contemporary concepts in a research area"?
2. What does it mean to "make use of the primary scientific research literature"?
3. What does it mean to "identify a specific question for investigation"?
4. What does it mean to "formulate a research hypothesis based on a specific question"?
5. What does it mean to "design an experiment or theoretical test of the hypothesis"?
6. What does it mean to an "understand the importance of controls"?
7. What does it mean to "make observations and collect data"?
8. What does it mean to "analyze numerical data"?
9. What does it mean to "interpret data by relating results to the original hypothesis"?
10. What does it mean to "reformulate the original hypothesis (as appropriate)"?
11. What does it mean to "relate results to the "bigger picture" in a research area"?
12. What does it mean to "orally communicate the results of research"?
13. What does it mean to "write a scientific report of research"?
14. What does it mean to "think independently about a research area"?

Part III: Science Practices

[Show the teacher the list of science practices.]

1) This is a list of science practices that was developed by the National Research Council and is included in the new national science standards. Please look them over and tell me how you think that are the same or different from the set of skills that we just talked about.

The science practices;

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

2) What does it mean to develop and use models?
3) What does it mean to use mathematics and computational thinking?
4) What does it mean to construct explanations?
5) What does it mean to engage in argument from evidence?

Appendix L: Poster Presentation Interview

1) What question are you trying to answer?
2) Where did you get the idea for doing that?
3) How does it fit in with the research being done by professor so and so etc?
4) Why did you use these methods?
5) How did you learn to use the methods?
6) What data did you collect?
7) How did you analyze the data?
8) How do your conclusions follow from your data?
9) How do you think your data, results, and conclusions will be used by your professor or graduate student mentor?
10) I see you cited this literature, how did you use it?

Appendix M: Permission for the Use of the Survey Items

Gmail by Google

Dilek Özalp <dilekozalp83@gmail.com>

survey from 2000 paper
4 ileti

Feldman, Allan <afeldman@usf.edu> 20 Eylül 2014 09:19
Kime: "carolanne.kardash@unlv.edu" <carolanne.kardash@unlv.edu>
Cc: Dilek Özalp <dilekozalp83@gmail.com>

Dear Dr. Kardash -

For a number of years I have been studying the development of teachers' and undergraduates' research skills when participating in research experiences. One of the ways in which I have collected data is to use a survey based on the items in your 2000 paper. All of my and my students' papers, presentations, and publications have cited your paper. One of my current students, Dilek Ozalp, is in the process of finalizing her dissertation. The Graduate School here at USF would like some confirmation from you that it is okay for her to use the items listed in your paper. I am attaching a pdf of an example SurveyMonkey form that uses your items. The other items relate to the research practices described in the Framework for K-12 Science Education.

Sincerely,

Allan Feldman

carolanne.kardash@unlv.edu <carolanne.kardash@unlv.edu> 20 Eylül 2014 11:56
Kime: "Feldman, Allan" <afeldman@usf.edu>
Cc: Dilek Özalp <dilekozalp83@gmail.com>

Hi Allan-
Thank you for your interest in my work. Yes, of course you have permission to use the items from my 2000 survey. I perused your instrument, and it looks interesting and informative. Several years ago, I collected information from RET teachers at the University of Missouri, but never did anything with it. I wish I had!

I wish you continued success, and good luck to Dilek with her dissertation. Please don't hesitate to contact me if the Graduate School requires further information from me.

Best, CarolAnne

Feldman, Allan <afeldman@usf.edu> 21 Eylül 2014 08:09
Kime: "carolanne.kardash@unlv.edu" <carolanne.kardash@unlv.edu>
Cc: Dilek Özalp <dilekozalp83@gmail.com>

CarolAnne – Thank you for your quick response.
Dilek looked at the teachers' understandings of the skills and the Framework practices. In general they came in with naïve understandings and left with them. Once she puts together an article we'll send it to you.

Allan

Dilek Özalp <dilekozalp83@gmail.com> 22 Eylül 2014 06:30
Kime: "Feldman, Allan" <afeldman@usf.edu>
Cc: "carolanne.kardash@unlv.edu" <carolanne.kardash@unlv.edu>

Dear Dr. Kardash

Thank you so much for your permission. Your survey was very helpful for me.

Regards,

Dilek

carolanne.kardash@unlv.edu <carolanne.kardash@unlv.edu> 22 Eylül 2014 10:39
Kime: Dilek Özalp <dilekozalp83@gmail.com>

Glad it helped. I look forward to reading your work!

Appendix N: IRB Approvals

UNIVERSITY OF SOUTH FLORIDA

DIVISION OF RESEARCH INTEGRITY AND COMPLIANC
Institutional Review Boards, FWA No. 000016€
12901 Bruce B. Downs Blvd., MDC035 • Tampa, FL 33612-47
(813) 974-5638 • FAX (813) 974-56

April 11, 2012

Allan Feldman
Secondary Education
College of Education EDU 105

RE: **Expedited Approval** for Initial Review
IRB#: Pro00007807
Title: Research Experience for Teachers: Water Awareness Research and Education

Dear Allan Feldman:

On 4/11/2012 the Institutional Review Board (IRB) reviewed and **APPROVED** the above referenced protocol. Please note that your approval for this study will expire on 4/11/2013.

Approved Items:
Protocol Document(s):

NSF-RET-WARE-IRB.docx	3/26/2012 6:09 PM	0.01

Consent/Assent Documents:

Name	Modified	Version
facultyConsentForm.pdf	4/11/2012 9:49 AM	0.01
teacherStudentRETconsentformRev.doc.pdf	4/11/2012 9:49 AM	0.01

Please note, the informed consent/assent documents are valid during the period indicated by the official, IRB-Approval stamp located on the form - which can be found under the Attachment Tab. Valid consent must be documented on a copy of the most recently IRB-approved consent form.

It was the determination of the IRB that your study qualified for expedited review which includes activities that (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the categories outlined below. The IRB may review research through the expedited review procedure authorized by 45CFR46.110 and 21 CFR 56.110. The research proposed in this study is categorized under the following expedited review category:

(5) Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for nonresearch purposes (such as medical treatment or diagnosis).

(6) Collection of data from voice, video, digital, or image recordings made for research purposes.

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval by an amendment.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

John Schinka, PhD, Chairperson
USF Institutional Review Board

Cc: Various Menzel, CCRP
USF IRB Professional Staff

USF
UNIVERSITY OF
SOUTH FLORIDA

DIVISION OF RESEARCH INTEGRITY AND COMPLIANCE
Institutional Review Boards, FWA No. 00001669
12901 Bruce B. Downs Blvd., MDC035 • Tampa, FL 33612-4799
(813) 974-5638 • FAX (813) 974-5618

May 8, 2012

Allan Feldman, PhD
Secondary Education
EDU 105
Tampa, FL 33620

RE: **Approved** Amendment Request
IRB#: MS1_Pro00007807
Title: Research Experience for Teachers: Water Awareness Research and Education

Dear Dr. Feldman:

On 5/4/2012 the Institutional Review Board (IRB) reviewed and approved your Amendment by expedited review procedures.

The submitted request has been approved **from date:** 5/4/2012 **to date:** 4/11/2013 for the following:

-Change in study staff: -Addition of Tina Hohlfeld as co-investigator -Addition of Dilek Ozalp as key personnel.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

John A Schinka, Ph.D.

John Schinka, PhD, Chairperson
USF Institutional Review Board

USF
UNIVERSITY OF
SOUTH FLORIDA

DIVISION OF RESEARCH INTEGRITY AND COMPLIANCE
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(813) 974-5638 • FAX (813) 974-5618

July 26, 2012

Allan Feldman, PhD
Secondary Education
College of Education EDU 105
Tampa, FL 33620

RE: **Approved** Amendment Request
IRB#: MS3_Pro00007807
Title: Research Experience for Teachers: Water Awareness Research and Education

Dear Dr. Feldman:

On 7/25/2012 the Institutional Review Board (IRB) reviewed and approved your Amendment by expedited review procedures.

The submitted request has been approved **from date:** 7/25/2012 **to date:** 4/11/2013 for the following:

-Change in instruments:
(A) In the approved study one interview protocol was used for both professors and graduate student mentors. The amended study has a separate protocol for professors and graduate students. The graduate student interview includes questions about their academic backgrounds, their current research, and their work with the teachers. Some of the professors were previously
interviewed for a study of Research Experiences for Undergraduates and were asked questions 1, 2, 7-13. Those professors will not be asked questions 1 or 2, and they will be asked if they have any changes to make in their responses to questions 7-13. In addition, question 11 in the original protocol was eliminated as not necessary for this study. New questions 13 and 14 were added to gauge professors' reactions to working with teachers.
(B) The original protocol for the teachers (mislabeled "students") in the approved study was modified to better match the goals of the RET program. It begins with questions about the teacher's reasons for choosing to participate in the program. It also asks them about their knowledge of the themes of the program. The protocol then asks a set of questions about the teachers' conceptions of the nature of science. The final set of questions is about the ways that the teachers teach their classes. The revised protocol includes questions about the teachers' academic background. These questions were removed.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

John A. Schinka, Ph.D.

John Schinka, PhD, Chairperson
USF Institutional Review Board

UNIVERSITY OF SOUTH FLORIDA

DIVISION OF RESEARCH INTEGRITY AND COMPLIANCE
Institutional Review Boards, FWA No. 00001669
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(813) 974-5638 • FAX (813) 974-5618

November 15, 2012

Allan Feldman, PhD
Secondary Education
College of Education EDU 105
Tampa, FL 33620

RE: **Approved** Amendment Request
IRB#: MS4_Pro00007807
Title: Research Experience for Teachers: Water Awareness Research and Education

Dear Dr. Feldman:

On 11/15/2012 the Institutional Review Board (IRB) reviewed and approved your Amendment by expedited review procedures.

The submitted request has been approved **from date:** 11/15/2012 **to date:** 4/11/2013 for the following:

Protocol Document(s):
NSF-RET-WARE-IRB v2 11/9/12(0.05)

Consent Document(s):
PI Consent form.pdf(0.01)

1. Change in study staff: Addition of Vanessa Vernaza-Hernandez as key personnel
2. Change in procedures/instruments:
(A) Addition of a follow-up interview of the teachers to get a better sense of what they have learned over the summer and how they are applying it to their teaching. New Teacher Final Interview script
(B) The PIs will be interviewed about the academic year component of the program. New PI interview script
3. Change in recruitment: New Telephone and email script for teacher follow-up interviews
4. Change in consent forms: New PI consent form, v1 dated 11/9/12
5. Revised protocol, v2 dated 11/9/12.

UNIVERSITY OF SOUTH FLORIDA

RESEARCH INTEGRITY AND COMPLIANCE
Institutional Review Boards, FWA No. 00001669
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(813) 974-5638 • FAX (813) 974-7091

5/30/2013

Allan Feldman, PhD
Secondary Education
College of Education EDU 105
Tampa, FL 33620

RE: **Expedited Approval for Amendment**

IRB#: Ame5_Pro00007807

Title: Research Experience for Teachers: Water Awareness Research and Education

Dear Dr. Feldman:

On 5/29/2013, the Institutional Review Board (IRB) reviewed and **APPROVED** your Amendment. The submitted request has been approved for the following:

-Change in instruments:
1. Revised interview scripts:
-Teacher Initial Interview, v2 52013
-Teacher Final Interview, v2
2. New interview scripts:
-Faculty conception of science practice v1 52013
-Teacher Follow-Up Interview, v1 52013
3. Revised surveys:
-Faculty and mentor research skills survey v2 52013
-Teacher Initial Survey, v2 52013
-Teacher Post Survey, v2 52013
4. Deleted surveys:
-BARSTL
-Final teacher and student survey
-STEBI-B
-Student and teacher research skills mid-survey
-Student and teacher research skills surveys.

ABOUT THE AUTHOR

Dilek Özalp graduated as an honor student with B.Sc & M.Sc (without thesis) degrees from Marmara University Chemistry Education Program, Istanbul, Turkey in 2006. She also received M.Sc (with thesis) degree from Marmara University Chemistry Education Program in 2008. During her undergraduate education, she was selected as a student assistant to work with research assistants in Marmara University analytical chemistry laboratory for three years. After graduation, she worked as a chemistry teacher at the high school level in Istanbul for three years.

She moved to the U.S to pursue her PhD degree in University of South Florida in 2010. In 2013, she was selected as a scholar from all over the world to attend Sandra K. Abell Institute which is a prestigious institute that serves for graduate students and a wide range of professors as mentors in science education field from all over the world to advance their research design, research methods and communication of research. As a PhD student at University of South Florida, she taught science methods, intermediate algebra and math workshop classes at the college level for several semesters and worked as a research assistant for different research projects in Environmental Engineering and Coalition for Science Literacy Programs. She presented at national and international conferences in science education and published articles in different journals.