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Experiencing Tightly and Loosely Structured Research Groups: The Influence on Preservice Science Teachers' Abilities to Engage in Science Practices

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ABSTRACT

There have been recent calls for students to not only learn the content of science, but also its practices. If teachers are to teach their students how to engage in those practice, then they need to have at least had some experience engaging in them. The US NSF research experiences for the teachers (RET) programs provide opportunities for the teachers to engage in those practices. In those programs, the teachers work in research groups that vary in the ways in which they are structured. This suggests they might gain different experiences depending on their research groups even if the teachers participate in the same program. Because of this reason, in this study we aimed to find out how participating in differently structured research groups influence preservice teachers' abilities to engage in science practices. By using a comparative case study approach, we compared two preservice science teachers' experiences and abilities in an RET program that required teachers to engage in research projects. Analysis of data from preservice teacher and graduate student mentor surveys and interviews, and observation notes indicated that the preservice teacher who participated in a loosely structured research group did not have the opportunity to improve in most of the practices and left the program as a novice researcher. On the other hand, the preservice teacher who participated in a tightly structured research group improved in most of the practices and to being a proficient technician.

Keywords: tightly structured, loosely structured, science practices, teachers' abilities

INTRODUCTION

In 2012, the National Research Council (NRC) published "*A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*," which began to use the term "practices" instead of the term "skills" to describe how scientific research is done. The framework describes in detail what these practices entails, and argues that by the end of 12^{th} grade, students ought to be able to engage in them at a sophisticated level. However, most science teachers have never participated in scientific research in their formal education (Capps & Crawford, 2013; Roseler et al., 2012), and therefore have not learned how to engage in the practices. This means many teachers are unable to teach their students according to the recommendations and requirements of the new *framework* (NRC, 2012) or the *next generation science education standards* (NGSS Lead States, 2013), and they possess naive conceptions of inquiry and the doing scientific research (Anderson, 2002; Blanchard et al., 2009; Ozalp, 2014; Roseler et al., 2012).

As science teacher educators, we try to provide preservice and in-service teachers with the teaching practices that will enable them to achieve the goals in their science education curriculum. If the teachers are expected to develop students' understandings of and abilities to engage in the practices of science, then teacher educators need to provide the teachers with the opportunities that will enable them to learn those practices. To achieve this, science teacher education should be designed in ways that support teachers to learn how to engage in science, and to teach their students the same (Osborne, 2014). Unfortunately, there is limited information about how the teaching and learning of the science practices should be implemented in classrooms or in science teacher education (Arias et al., 2016; Osborne, 2014).

One way to help teachers learn the practices of science is by providing them with research opportunities. The United States National Science Foundation (NSF) research experiences for teachers programs (RETs) (NSF, 2012) provide teachers with the opportunity to engage in authentic scientific and engineering research projects and help them translate their research experience into classroom teaching (NSF, 2012; Roseler et al., 2012). RETs can be an important way for pre- and in-service science teachers to learn how to do science. However, differences in RETs including the ways in which pre- and in-service teachers, scientists, and graduate students interact with one another can have an effect on the pre- and in-service teachers' learning to do research. Therefore, in this study we focused on the connections between the experiences of pre-service teachers (PSTs) in research groups and their development as researchers.

LITERATURE REVIEW

The literature on short-term research experiences such as RETs demonstrates that teachers' participation in the research experiences with scientists can improve their understandings of scientific inquiry (Bahbah et al., 2013; Blanchard & Sampson, 2018; Buxner, 2014; Herrington et al., 2016), perceptions of inquiry (Peters-Burton et al., 2015), confidence in science and inquiry (Cutucache et al., 2017), and views of scientific inquiry (Hughes et al., 2012). However, it has also been demonstrated that the teachers' conceptions of the practices of science remain naïve even after completing an RET (Ozalp, 2014).

While RETs can help teachers to increase their understanding of how science is done, they have varying influences on teachers' pedagogical beliefs and translation of their experiences into classroom practices. RETs can help shift teachers' beliefs from a teacher-centered to a more student-centered approach (Miranda & Damico, 2015), and lead them to be more receptive to inquiry teaching (Miranda & Damico, 2013; Enderle et al., 2014; Herrington et al., 2016; Southerland et al., 2016).

Teachers in RETs made substantial gains in understanding the nature of science with explicit instruction (Schwartz et al., 2004), improve teachers' understanding of research process (Buxner, 2014; Klein, 2009) and their ability to relate this to their students (Klein, 2009), increased content knowledge, and enthusiasm for science (Westerlund et al., 2002). Although RETs 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 (Roseler, et al, 2012). In addition, RET programs improve teachers' functionality as scientists (Faber et al., 2014), increase their understanding of design-based learning, workforce skills (i.e., 21st century skills), and the engineering design process skills (Bowen et al., 2021), improve teachers' confidence and growth in their understanding of STEM curriculum (Schneider et al., 2020) and their inquiry conceptions and lesson design (Blanchard & Sampson, 2018), and increase STEM awareness teaching practices potentially contribute to preparing more students for STEM careers (Pinnell et al., 2018).

Although the literature on RETs shows that participation in these programs helps teachers to improve their teaching practices, the improvements are often limited even when there was follow-up that engaged teachers in further reflection on their practices (Blanchard et al., 2009). Studies reported limited changes from the use of teacher-centered to reform-based practices (Dixon & Wilke, 2007; Miranda & Damico, 2015), limited long-term changes in their inquiry-based teaching (Peters-Burton et al., 2015), and little engagement of their students in science practices (Grove et al., 2009).

Although not as common as RETs for in-service teachers, science research experiences are also provided for preservice science teachers. Their effects on the preservice teachers are similar with the effects of RETs on in-service teachers. Those research experiences help PSTs to improve understanding of how science is conducted and how to implement new pedagogical strategies (Raphael et al., 1999), self-motivation and skills in communication and critical analysis (Melear et al., 2000), science content knowledge (Gilmer et al., 2002), and improvements in a conceptually oriented view of science teaching (Langford & Huntley, 1999). Although PSTs acquired scientific skills and content knowledge, they expressed limited use of these in their classrooms (Brown & Melear, 2007).

As seen above, the literature on pre- and in-service teachers' short-term research experiences such as RETs does not focus on the changes in the knowledge and skills needed to engage in scientific research. In addition, none of these studies provided detailed information about the individual experiences of the pre- and in-service teachers. We believe that this is necessary because RETs vary from one another, and even when pre- and in-service teachers engage in the same RET program, they could have different experiences. In particular, they may have widely varying experiences because of the nature of the faculty members' research groups. Teachers' experiences such as participating in weekly debriefing group meetings (Herrington et al., 2016) and mentoring relationships (Hughes et al., 2012) are some of the important factors that might affect pre- and in-service teachers' understandings of scientific research in RETs. Therefore, there is a need to uncover the connections between the experiences of PSTs in research groups and their development as researchers if RETs are to be successful in preparing PSTs to teach the practices of science.

In this article, we compare and contrast cases of two PSTs who participated in the same RET during the same summer but had very different experiences related to the structure of their research group. This enabled us to investigate the following questions:

1. Did participating in research groups with different structures influence the PSTs' abilities to engage in science practices in the RET programs?
2. If yes, how did participating in research groups with different structures influence the PSTs' abilities to engage in the practices of science?

LEARNING TO DO RESEARCH IN RESEARCH GROUPS

Feldman et al. (2009, 2013) developed a model for how students learn to do research based on their study of undergraduate and graduate students engaged in research groups as part of an interdisciplinary science research study.

Apprenticeships

Using a sociocultural theoretical framework (Bandura 1969, 1971; Bryman, 2001; Vygotsky, 1962), they found that the students learned how to do research by participating as apprentices in the research groups. According to Lave and Wenger (1991), to be an apprentice is to engage in legitimate peripheral participation in a community of practice, which results in the situated learning of skills and knowledge needed to become an expert in the field. The students learn to do research by engaging in research. Their supervisor, typically the head of the research group or a more expert member of the group gives the students tasks appropriate to their skill levels. As they demonstrate that they've learned how to complete the tasks, the supervisor gives them more complex tasks. In this way they engage legitimately in the research group, and more from the periphery toward the center.

Research groups are both communities of practice (Wenger, 1998) and epistemic communities (Haas, 1992). Communities of practice are groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly. Epistemic communities are ones that have as their goal the production of knowledge. According to Hass (1992), its members–scientists, students, and others–have recognized expertise and competence in a domain of science and have an authoritative claim to knowledge within that domain.

As the students progress through their apprenticeships, their roles in their research groups change from novice researcher to proficient technician to knowledge producer. We wanted to note that although in our research the participants are preservice teachers, in this section we refer the participants as students because the studies that have been done on the research groups included undergraduate students. In addition, the process of learning how to do research is similar for undergraduate students and pre- or in-service teachers since in general all of them are novices who did not have substantial research experience before participating in the research groups. Novice researchers are new to research and have little of the knowledge and skills needed to engage in it. As they learn by participating in the group, they develop the skills needed to collect and analyze data, to report results to other researchers. Feldman et al. (2009, 2013), using the language of the scientists in the interdisciplinary study; refer to this role as proficient technician. Finally, through continued participation in the research group, the students become able to integrate information from their field and other domains, formulate research questions, draw defensible conclusions from data, and create, disseminate, and defend new knowledge that is a contribution to the field. The students neither self-select into these roles nor do their supervisors assign a role. Although Feldman et al. (2009, 2013) described these roles in a way that may suggest that they are distinct stages of development, they make clear that the roles are along a continuum of learning how to do research, and that students can develop along that continuum at different rates.

Feldman et al. (2009, 2013) described the characteristics of each of the roles according to the ideas of methodological and intellectual proficiency. Methodological proficiency is needed to be able to engage in scientific research as a practitioner. By having this type of proficiency, researchers can engage in specific techniques, use major instruments and protocols, modify techniques, and develop new ones, transfer established techniques to novel situations, exhibit familiarity with research and research methods, and use published methodologies and innovating new ones (Feldman et al., 2009). Intellectual proficiencies are those that a researcher needs to be able to contribute to the construction of new knowledge and provide sufficient warrants for it to be accepted in the field. We use these labels to distinguish between practices that are associated with proficient technicians, and those associated with knowledge producers.

Research group participants can develop from novice researchers to proficient technicians to knowledge producers by developing methodological and intellectual proficiency. Novice researchers have little or no experience with scientific research and therefore they have little in the way of either type of proficiency. If they remain in the research group for only a short time, they will most likely develop only some methodological proficiency. Novice researchers can develop into proficient technicians by engaging in legitimate peripheral participation (Lave & Wenger, 1991) for a longer time period. They further develop their skills to collect and analyze data as they gain methodological proficiency, to the point of becoming experts in standard research methods. They are not expected to formulate research questions, but they can apply the methods they have learned to new situations, and eventually be able to report results of their research. As proficient technicians continue to participate in the research group, they can continue to improve their intellectual proficiency and develop into knowledge producers. Based on Feldman et al. (2009, 2013), we prepared **Table 1** to show our conception of the relationship between the roles, types of proficiency, and science practices.

Structure of Research Groups

Feldman et al. (2009, 2013) found that research groups can be structured along a continuum from being *loosely structured* to *tightly structured*. These structures depend on the interactions among the group members (Feldman & Ozalp, 2011, 2012). The center for action is the main difference between the two types of research groups. Feldman et al. (2009, 2013) found the laboratory was the center of the action for tightly structured research groups. In these groups, the professors played an important role in developing the groups and facilitating interactions among the students. The group members in the tightly structured groups participate in regular research group meetings and journal clubs to discuss their research and the literature reviews, share their knowledge and skills about their research, have informal discussions with their professors, and engage in social activities together. In addition, regular and frequent interactions among the students in the laboratory provided them with the opportunity to learn from one another, and therefore facilitate their learning how to do research. The centers of action in the loosely structured research groups were the professors. In this structure, group members work individually. The professors meet individually with the students to discuss their research

Table 1. Science practices and proficiencies of novice researcher, proficient technician, and knowledge producer

Proficiency	Novice researcher	Proficient technician	Knowledge producer
Methodological proficiency	Make observations & collect data	Make observations & collect data	Make observations & collect data
	Orally communicate the results	Orally communicate the results	Orally communicate the results
		Interpret data	Interpret data
		Understand importance of controls	Understand importance of controls
		Analyze data	Analyze data
		Use mathematics & computational thinking	Use mathematics & computational thinking
		Make use of the literature	Make use of the literature
		Write scientific research reports	Write scientific research reports
Intellectual proficiency		Develop & use models	Develop & use models
		Think independently*	Think independently
		Design experiments*	Design experiments
			Understand fundamental concepts
			Identify a question
			Formulate a hypothesis
			Reformulate the hypothesis
			Relate results to the bigger picture
			Construct explanations
			Engage in arguments

Note. *Some novice researchers engage in those practices, but proficient technicians & knowledge producers are more able to engage in them

progress. Student-student interactions are limited because students' connections to the group are through the professors (Feldman et al., 2009). While the structure of research groups may be discipline-specific, the personal characteristics of the professors apparently affect how the groups are tightly and loosely structured. It is also possible personal characteristics of the other group members have an effect on these types of structures (Feldman et al., 2013).

Although our study relies on the Feldman et al.'s (2009, 2013) categorization of structures of research groups, we searched for how others describe them. For example, Valente (2018) found that research groups that have characteristics similar to ones that are tightly organized provide support for participants to improve their understandings of the nature of science. Similarly, Elizondo-Omaña et al. (2019) found that well-structured, formal research groups that integrate faculty from different fields through a collaborative mentoring model increases training, experience, and scientific output. Kobulnicky and Dale's (2016) community mentoring model has similarities with the tightly structured research groups. In it, the mentee is a member of what they describe as an authentic 21st century scientific community of practice that includes peer-mentoring, communications, teamwork, and community learning.

METHODS

In this study, we used a comparative case study approach (Yin, 2014) to provide an in-depth analysis of two PSTs who participated in an environmental engineering RET program. It is important for us to make clear that although the research groups were in engineering, what happened in them was much more in line with what the *framework* (NRC, 2012) describes as science practices than engineering practices. The everyday practices in the environmental engineering laboratories were indistinguishable from the everyday practices that would be observed in a science research lab. Although the research was applied in the sense that it had real-world implications, all of the practices used in the labs were those of science. In brief, the engineering faculty members' research went beyond solving problems and designing solutions, to understanding the phenomena involved and producing new knowledge about them. This can be seen, for example, in the methods described in the publications that came out of the research projects done that summer.

Context: The RET Program

The setting of the study was a six-week RET program supported by the NSF. It was located in a research-intensive university in the southeast United States. 15 middle and high school science teachers (five pre-service and 10 in-service) participated in projects on management of the nitrogen cycle, access to clean water, and urban water infrastructure improvement. The PI and Co-PIs selected the participants based on their application materials, including letters of recommendation, previous experience, and for in-service teachers, a supportive letter from their school principal.

Six professors and their eight graduate students mentored the fifteen teachers. Pre- and in-service teachers were provided with an orientation, which included safety training, a tour of the research settings, and how to do library searches. They started their research in week one and they continued to do it until week five. During week six, they finalized their research, finished their research posters, and presented their posters with graduate students in a poster presentation session.

Other than the orientation, there were no program-wide activities to scaffold the pre- and in-service teachers' learning to do research. Most of the graduate students participated in a one-credit seminar on mentoring novice researchers to help them improve their mentoring skills. Author 2, who is a science education professor, gave a presentation in the mentoring seminar on his model of learning to do research. The pre- and in-service teachers did receive guidance in the construction of lesson plans based on their research experiences. They were encouraged to publish these plans in the online compendium, TeachEngineering.org. Author 1 was a doctoral student in science education and was supported by the RET program. As part of her role, she participated along with the pre- and in-service teachers in the RET activities.

Selection of the Cases

We selected two of the PSTs, Ivette and Ashlynn (pseudonyms) to be the focus of this study. We chose them because of the differences we observed in the structures of their research groups, and that our data showed the highest levels of contrast in their abilities to engage in science practices. Although both Ivette and Ashlynn were PSTs, that is not the reason why we chose them. The selection was done by identifying the pre- or in-service teachers who improved the most and who improved the least. Our analysis of data indicated that it was Ivette who improved the most among the RET participants, and Ashlynn who improved the least. In addition, we found that their research groups differed in terms of the frequency and variety of the research group meetings; the opportunities to interact with all the group members, including the professor and the graduate students; and frequency and variety of the social gatherings of the research group. These differences are related to the structure (tightly or loosely) of the research groups. Therefore, those RET participants were selected to show how participating in research groups with different structures influenced their abilities to engage in the practices of science. These differences will be made clear in our findings below.

The Pre-Service Teachers

Ivette

Ivette, who is Latina, was a student in the undergraduate secondary science education program with a specialization in chemistry at the time of the study. The program included content courses that added up to slightly more than a minor in the discipline, two science teaching methods courses, and other education courses such as adolescent development, teaching English language learners, and measurement. Ivette had not participated in an RET program before, and the only research experience she had was in high school. That research was about fruit flies, and her primary job was to remove the ovaries of the fruit flies.

Ivette worked with a graduate student (Linda) and a professor (Sarah) in this RET program. Linda was a PhD student and research assistant in the civil and environmental engineering department under the supervision of Sarah. Linda had over three years of research experience focusing on drinking water treatment, point-of-entry treatment, biosand filters, disinfection by-products, aquaculture, on-site wastewater treatment systems, and trace organic and nutrient removal. Sarah's research focuses on the use of biological processes to clean wastewater. The PSTs worked with the graduate students to help the latter with their research projects. The expectation in Sarah's group was that results from PSTs' research would be useful for the graduate students. Therefore, we provided the graduate student background and the details about their research here to help the reader understand what the research was that the PSTs were actually doing. In addition, the graduate students provided data about the teachers' abilities in science practices. Therefore, their background is also important to understand their expertise in the research area.

Ivette's research project was part of Linda's research. The purpose of Ivette's research project in the RET program was to investigate how to remove the off-flavor compounds in aquaculture tanks that accumulate in the fish. Her research questions were how the usage or storage affects the qualities of the fish food, and how that affects the water quality in the recirculating aquaculture system. Ivette performed various water quality measurements including pH, dissolved oxygen, ammonia, nitrate, nitrite, and conductivity and did the appropriate data analysis to answer her research question. Ivette used Excel to analyze the data to determine if the measurements 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 created the figures to see daily changes. Linda 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. Every time they did the experiment, Ivette sat down and discussed with Linda about what was happening and what they were seeing in the experiments. She presented her research in the lab tour and NSF research day.

Ashlynn

Ashlynn, a white female, was a student in the Master of Arts in Teaching (MAT) secondary science education program. Her program had more science education methods courses but no content courses. It also included graduate equivalents of the education courses in Ivette's program. Ashlynn began the program after receiving an undergraduate degree in biology. Ashlynn and Ivette had been enrolled the previous academic year in the same middle school and high school science teaching methods classes. She had not participated in an RET program before. Both in and out of college, she worked for a dolphin research project at a marine lab. 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 performed dolphin predator-prey studies, going out in a boat to collect fish and study features such as size and type of fish. She also worked in an environmental organization and most recently spent four years at a small aquarium teaching environmental science and marine science.

In the RET program, Ashlynn's research group included the professor, Mia, her graduate student mentor, Sally, and an in-service teacher, Pat, who was also a participant in the RET program. Sally was a PhD student under the supervision of Mia. Sally's research focused on collecting and analyzing water samples on two novel aquaponics systems and analyzing dried plant samples for total nitrogen and total phosphorus. Mia has a wide range of research interests including sustainability, water quality, ecotourism, and small-scale mining impacts on sustainable livelihoods. Ashlynn's research project was part of Sally's research.

The purpose of Ashlynn's project was to measure the transformations of nitrogen during the start-up phase of the aquaponic system. Her research question was how long it takes to produce an effective nitrogen cycle from the beginning. She collected data to test water samples for nitrate, total nitrogen, phosphate, dissolved oxygen, total phosphorus, chemical oxygen demand, ammonia, and reactive phosphate. In terms of the literature review, she was not given much information; she only reviewed a few articles for the poster she presented at the spend of the program. Ashlynn did not design an experiment because the graduate student had her project and from that they worked on water quality. She presented her research in the lab tour and NSF Research Day. Pat was also involved in this research project.

Data Collection

Our data sources included surveys and interviews of the PSTs and graduate students, and observations of the PSTs engaged in their research activities.

Pre-service teacher surveys

PSTs were surveyed three times during the program, at the beginning, midway through, and at the end. Each time the survey was administered the PSTs were asked to rate their ability to engage in the science practices at that time. The mid survey also asked them to reflect back to the beginning of the program and to rate their abilities from their new perspective.

The survey used was the teachers' abilities engaging in science practices, which consisted of 18 Likert-scale items that asked the PSTs to what extent they believe 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. Fourteen items in the surveys were adopted from Kardash's (2000) research skills survey. Kardash (2000) tested the instrument with undergraduate researchers and faculty mentors and reported the coefficient alpha for undergraduate researchers as .90, and item–total correlations ranged from .49 to .76. The internal consistency for the faculty mentors was .96, with item–total correlations ranged from .78 to .88.

The skills included in Kardash's (2000) survey are similar to the science practices as described in the *framework* (NRC, 2012). Some of the similarities are apparent. For example, Kardash's (2000) skill "identify a specific question for investigation" corresponds to the practice "asking questions". Other practices, such as "constructing explanations" include several of Kardash's (2000) skills. Therefore, we added an item to our survey that specifically asked about constructing explanations to reduce the ambiguity. Three items were added to Kardash's (2000) instrument to make the survey more in line with the practices of science as described in the *framework* (NRC, 2012).

Content validity was used to establish the validity of the teacher survey. Then two professors were asked what they thought about the content and whether it represented all the science practices. 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. 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.

Graduate student survey

We made modifications to the teachers' abilities engaging in science practices survey to use it to obtain the graduate students' perceptions of the PSTs' abilities to engage in science practices. It asked the graduate students to what extent the PSTs had the ability to engage in the 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. The graduate students observed and interacted with the PSTs from the beginning to the end of the program so this allowed them to get information about the PSTs' initial and final abilities. Because this survey was administered at the end of the program, the graduate students' ratings of the PSTs' abilities at the beginning of the program were retrospective. Example questions can be seen in **Appendix A**.

Pre-service teacher interviews

We interviewed the PSTs after the program ended to gain more information about their views on why they thought their abilities to engage in the practices improved or did not. The interview protocol included 18 items. The semi-structured interview protocol included the 18 science skills and practices as in the survey.

Graduate student interviews

We also conducted semi-structured interviews with the graduate students. They were asked how the PSTs' abilities to engage in the practices changed during the summer and why they thought they improved or stayed the same. This interview protocol included 23 items. Because the surveys relied on the PSTs' self-reports, having additional qualitative data from the graduate students helped us to better triangulate our results.

One of the purposes of the graduate student interview was to understand how they rated the PSTs in the surveys. In the interviews, they explained why they thought the PST improved or did not in the science practices. During the interview, we showed the graduate students the ratings from their surveys and requested them to explain the reasons for their ratings. In the PST interview, we asked the PSTs to explain why they thought they improved in the practices (see **Appendix A** for an example of this type of question).

Observations

During the program, each PST was observed individually while they worked with their mentors in the lab for two hours, in the lab tours (where they explained their research to the RET program team) for one hour, in the NSF research day (poster presentation session) for half an hour, and in the several workshops of the RET program. Author 1 made all the observations. The observation protocol focused on PSTs' abilities to engage in science practices and the interactions within their research groups. We used the observation data to support our data in the surveys and interviews.

Prolonged engagement, peer debriefing, data triangulation, member checks, and time sampling strategies were employed to establish the credibility (internal validity) of the qualitative data. In addition, data triangulation and peer examination were conducted to establish the dependability (reliability) of the qualitative data (Anfara et al., 2002).

Table 2. The criteria to determine the amount of PSTs' improvement in science practices

<table>
<tr><th colspan="2">Criteria</th><th>A lot</th><th>A little less</th><th>Very little</th><th colspan="2">Not at all</th></tr>
<tr><td rowspan="2">DIF</td><td>GS</td><td>2</td><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>PST</td><td>2 or 1</td><td>2 or 1</td><td>1 or 0</td><td>1</td><td>0</td></tr>
<tr><td colspan="2">Interview</td><td>GS & PST concurred with improvement & gave reasons for it.</td><td>GS & PST concurred with improvement & gave reasons for it.</td><td>GS & PST concurred that there was little improvement, or there was not much improvement.</td><td colspan="2">GS & PST concurred with that there was no improvement.</td></tr>
<tr><td colspan="2">Observations</td><td>We observed that PSTs were able to engage in this practice.</td><td>We observed that PSTs were able to engage in this practice.</td><td>We observed that PSTs had limited ability in this practice.</td><td colspan="2">We observed that PSTs were not able to engage in this practice.</td></tr>
</table>

Note. DIF: Differences between pre-post survey ratings & GS: Graduate student

Data Analysis

To analyze the survey data first we attached numerical values to the responses: not at all: 1, very little: 2, somewhat: 3, quite a bit: 4, a great deal: 5. Then, we graphed each item from the PST and graduate student ratings to show the changes in the PSTs' abilities to engage in the practices before, in the middle and at the end of program.

The PST and graduate student interviews were transcribed, and we provided direct quotes of the PSTs and graduate students in the findings section. The quotes presented were selected on the basis that they most aptly represented the views of the PSTs and graduate students on how the PSTs' abilities to engage in the practices changed in the program and what might be the factors that explain those changes.

We used three criteria to determine the amount of improvement in each science practice: The differences between the pre-post survey ratings, the interview responses, and our observations. We first, looked at the differences in the graduate student ratings (the highest is 2 the lowest is 0), and then the differences in preservice teachers' ratings (the highest is 2 the lowest is 0). The interviews played an important role in the categorization as well. For example, as you can see in **Table 2**, if the difference in the graduate student rating is 1 and the difference in the PST rating is 1, this practice could be under a little less or very little categories. If in the interview the graduate student noted that there was not "much improvement", this practice was put under very little. If in the interview the graduate student said the PST improved in this practice, then it was put under a little less. Similarly, for a practice in which the difference in the graduate student's rating was 1 and the difference in the PST rating is 0, it could under very little or not at all. If in the interview the graduate student noted there was not "much improvement" then the practice was put under a little less. However, if in the interviews, the graduate student or PST said there was not an improvement, their research did not include this practice, or the PST did engage in this practice, it was put under NOT AT ALL. For detailed explanation of all the categorizations, please see the **Appendix B**.

FINDINGS

In this section, we begin by presenting information about Ivette and Ashlynn, their research groups, and their experiences in the program. The purpose is to provide readers with a sense of what the PSTs experienced in the program. This includes information about their backgrounds, the structure of the research groups, and how they typically interacted with their mentors. This is important because our goal is to show how the nature of their experiences in the two types of groups affected the development of their abilities to engage in science practices. We then provide in-depth analysis of each case by examining them separately. In the discussion and conclusion section, we compared those two cases based on the findings regarding the structure of the research groups and PSTs' abilities to engage in science practices.

The Research Groups

As we noted above, we selected Ivette and Ashlynn as cases because of the differences in the structures of their research groups, and because of the differences in their outcomes as a result of participating in the RET. Before describing them, we want to note that if you were to observe the day-to-day activities of each of the research groups as we did, you would see the graduate students and their advisors engaged in the practices of science needed to produce high-quality, warranted findings that are publishable and suitable for master's theses and doctoral dissertations at a research-intensive university. We lack the space in this article to describe this fully, but overall, there is little difference from what has been reported by other researchers of the doing of science (Keely, 2020; Labouta et al., 2018; Valieda, 2001).

Sarah's research group

Ivette participated in Sarah's research group, which based on our observations we found to be tightly structured (Feldman et al., 2009). Sarah was a professor in the environmental engineering program. Each week Sarah met with her research group, which typically consists of doctoral, masters, and undergraduate students. Some of these meetings were set up as journal clubs, in which the participants select relevant journal articles that are read by everyone in the group, and then engage in a discussion about it (Golde, 2007). At other times, the research group meetings were used for the members to make reports about their progress, to seek assistance with problems that they are having, or to practice conference presentations. The research group meetings take place in a seminar room next to Sarah's laboratory, which is where almost all of her students do their research. In addition, the students have their desks in a room adjacent to the lab. As a tightly structured research group, the center of their action was the laboratory because all of Sarah's students work together in the same laboratory to do their research. As a result, students have many opportunities to interact with one another. Sarah also hosts social gatherings of the group at her home, takes students out for celebratory meals, and goes to

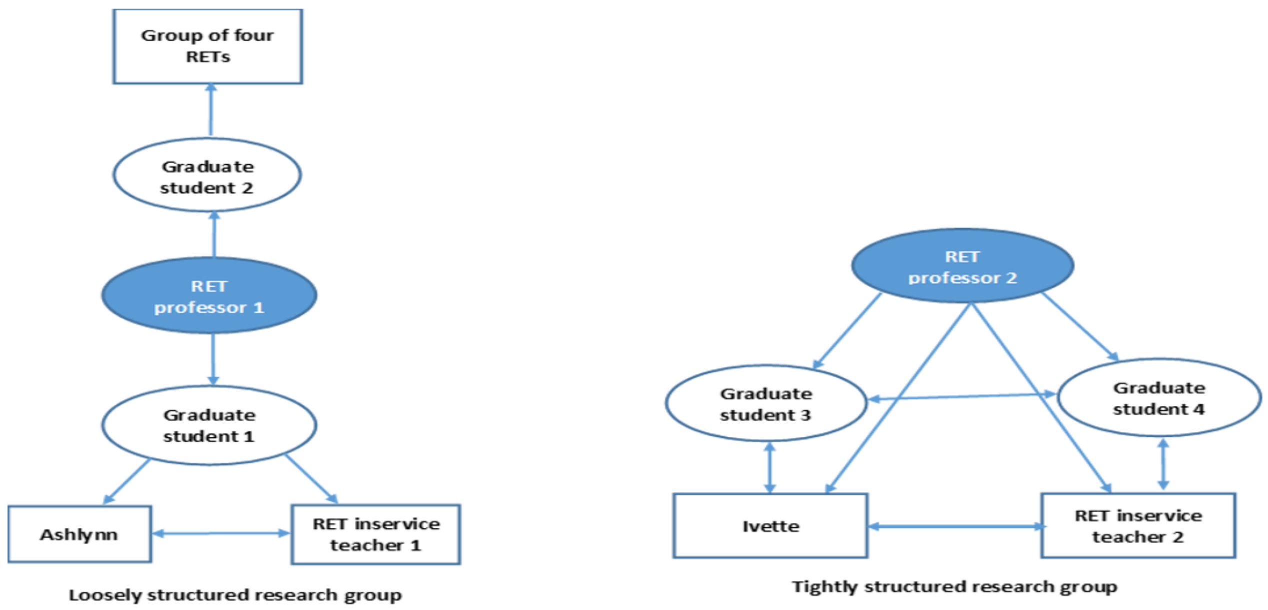

Figure 1. Web of connections among participants in research groups

their life event parties such as birthdays, weddings, and baby showers.

In these research group meetings, Ivette had many opportunities to interact with Sarah, her mentor Linda, and other graduate students. Linda asked her to join their Dropbox documents group, so she was exposed to a lot of the literature about their research. They then discussed a couple of experiments that they needed to perform for the research. After the discussion, Ivette and Linda decided on her research questions. Ivette designed the experiments with Linda's help. In the beginning of the RET program, Linda taught her how to do the basic measurements. Ivette's research did not include a control, but she discussed with Linda whether they needed to use a control in their research. Linda gave her a quick Excel course to analyze the data. Every time they did the experiment, Ivette sat down and discussed with Linda what was happening and what they were seeing in the experiments.

Mia's research group

Ashlynn participated in Mia's research group, which based on our observations, we found to be loosely structured (Feldman et al., 2009). Mia was a professor in the environmental engineering program. During the RET, Mia was out of the country for most of the summer. Therefore, she was not available to plan or facilitate the types of gatherings that Sarah had for her group. We do have some anecdotal data that when she is at the university, she has research group meetings and social events for her students. However, another factor that comes into play is whether the graduate students are working on the same research program. While this is the case for Sarah's students, Mia's students work on a range of projects that do not necessarily connect to one another. That reduces the likelihood that they would be helping each other out in the way that is seen in Sarah's group. In addition, the site for Sally's research was not in the laboratory building. Because Sally's focus was on aquaponics, she needed to have her systems set up outdoors. The best site for that was a greenhouse in the botanical gardens on campus, which was about one kilometer from the lab. While Sally would need to go to the lab with her samples to do analysis, much of her time was spent in the greenhouse away from other members of Mia's group. Therefore, Ashlynn mostly worked with only Sally and Pat in her research. Ashlynn and Pat worked closely throughout their research except the data analysis part. Ashlynn stated she was not interested in analyzing the data, so she left that part to Pat.

Because Mia was out of the country for most of the summer 2013, Ashlynn had little contact with her. This was one of the most important indicators of a loosely structured research group. Mia and Ashlynn did not have in person meetings to discuss the project therefore the research collaboration between them were limited in the summer. Instead, Mia relied on Sally to oversee Ashlynn's participation in the RET. Without Mia's expertise, Sally was primarily directive in her mentorship, basically providing Ashlynn with the research question and directions to follow. Ashlynn read little of the pertinent literature and was not given much other information. Ashlynn did not design an experiment; rather she assisted Sally with her research project on water quality.

Sarah's tightly connected and Mia's loosely connected research groups are shown in **Figure 1**, which provides a graphical representation of the ways in which they interacted with the graduate students and the teachers. Mia (RET professor 1) and Sarah (RET professor 2) were professors in the environmental engineering program. Each of them supervised two graduate students who mentored the teachers. Mia's research group included two graduate students Sally (graduate student 1) and another (graduate student 2). Sally mentored Ashlynn and Pat (RET in-service teacher 1). Ashlynn and Pat worked on the same research project. Graduate student 2 mentored four in-service teachers (RETs). All of these in-service teachers worked on different research projects. Sarah's research group included Linda (graduate student 3) and another (graduate student 4) as graduate students. Linda mentored Ivette and graduate student 4 mentored one in-service teacher (RET in-service teacher 2). Ivette and the in-service teacher worked on different projects.

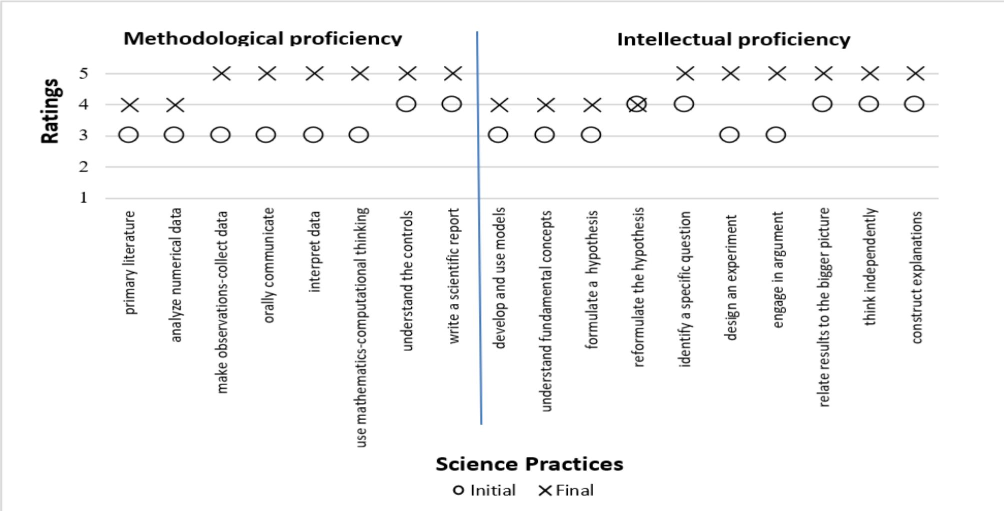

Figure 2. Graduate student's ratings of Ivette's abilities to engage in science practices (1-Not at all, 2-Very little, 3-Somewhat, 4-Quite a bit, and 5-A great deal)

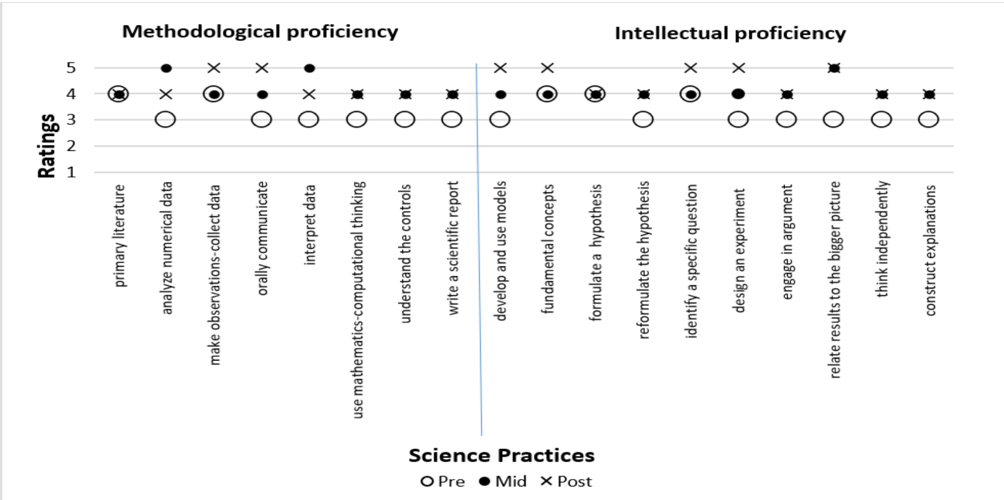

Figure 3. Ivette's self-reported pre-, mid-, and post-survey ratings of her abilities to engage in science practices (1-Not at all, 2-Very little, 3-Somewhat, 4-Quite a bit, and 5-A great deal)

Figure 1 illustrates how there were more possibilities of student-student and student-RET connections in Sarah's tightly connected research group than in Mia's loosely connected group. As it can be seen, Mia directly interacted with her graduate students but not with the pre- and in-service teachers. Also, Sally and Graduate student 2 did not have direct interactions. On the other hand, Sarah directly interacted with both the pre- and in-service teachers and her graduate students. In addition, there were direct interactions between Linda and graduate student 4, and between Ivette and the in-service RET teacher.

Pre-Service Teachers' Abilities to Engage in Science Practices

We now look closely at what our data indicates about changes in Ivette's and Ashlynn's abilities to engage in the practices of science.

Ivette

According to the survey completed by Linda, the graduate assistant who supervised Ivette, all of Ivette's abilities to engage in science practices improved from the beginning to the end of the program (**Figure 2**). Ivette also reported ratings in the surveys that her abilities to engage in science practices improved in the program, except for *making use of the primary scientific literature* and *formulating a hypothesis* (**Figure 3**). Although Linda thought Ivette improved in those two practices a little bit, they were among the lowest rated abilities by her as well. Linda explained that as "we did not get to reformulate the original hypothesis because we saw what we expected but I think she is able to do that…"

The survey results indicated that for Ivette, her abilities to *understand fundamental concepts, identify a specific question for investigation*, *design an experiment*, *make observations, and collect data*, *orally communicate the results of research*, and *develop and use models* increased from the mid- to the post-surveys. Similarly, Linda's ratings indicated Ivette improved on those practices from the beginning to the end of the program. In addition, both Ivette's post-survey and Linda's survey indicated that these are among the highest rated practices for Ivette. Linda told us that reading the literature, working in the lab, and participating in the research group meetings played an important role for Ivette to improve her ability to *understand the fundamental concepts*. Ivette's participation in those meetings and her interactions with the Linda was an important aspect of a tightly structured research group; and this tight organization was crucial for her improvement in understanding the fundamental concepts of her research. Linda told us Ivette could "understood why we were seeing those differences in the water quality, and she could explain what we were working on" as a result of "working in the lab and by reading and being in our meetings".

Linda explained Ivette's improvement in *designing an experiment* as "Yes, I guess with knowledge, reading previous papers and everything I think she is capable of developing an experiment based on what they need..." She thinks that her discussions with Ivette about the experiments and the research had an important role in the improvement of her ability to *identify a specific question for investigation*. Linda told us:

> "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..."

We see here an important aspect of a tightly structured research group–Linda had the opportunity to discuss Ivette's progress in the RET with Sarah.

Linda told us the following about Ivette's improvement in *making observations and collecting data* "she learned a lot in the first couple of weeks, later she was able to do her own tests and collect her data". In our lab visits we observed Ivette was able to run the tests to collect data measuring conductivity, pH, COD (chemical oxygen demand), and turbidity for different water samples, and able to record her observations.

Ivette's improvement in *orally communicating the results of the research* as shown in the surveys, was also supported by our observations of her work in the laboratory and in her poster presentation. We saw an improvement in the way she explained her research and its components such as the research question, how she collected, analyzed, and interpreted the data, and how she made connections to the bigger picture. This agrees with Ivette's post- survey ratings and Linda's ratings in the final survey indicated that *relating results to the bigger picture* was one of the highest rated practices for Ivette. Linda explained Ivette's improvement, as:

> "...because of the part that she was doing she understood why it was important to do the experiment...and every little experiment was part of this huge puzzle that is the research we are working on."

Ivette's self-ratings for *analyze numerical data* and *interpret data by relating results to the original hypothesis* were the highest ones in the mid-survey. Although Ivette lowered her ratings later in the post survey, Linda' ratings and the interview data also supported that her abilities to engage in those practices improved over the six weeks. In the interview, Ivette expressed her thoughts about her ability to engage in *data analysis* and the support that she got from her mentor, Linda, as "...it means to me the most hard ever, it is really hard, I am still learning ... I had a lot of help from my mentor, and she then gave me like a quick Excel training to analyze my data". Linda, as well, expressed her thoughts about Ivette's improvement on this practice as:

> "So, this one I gave her like a crash course in Excel. So, I think she learned a lot from that...And *interpreting the data*, every time we did the experiment she sat down, and we discussed what is happening...so I think she has great deal knowledge in that too."

As above, Ivette emphasized the help that she got from Linda on her improvement in *collecting and interpreting the data*. She stated "I really got a lot of help from my mentor and also help on my research so I can better understand the expectations ..." Here, we see an important aspect of tightly structured research group. Close interactions with Linda improved Ivette's ability to engage in collecting, analyzing, and interpreting the data.

Ivette's self-reported ratings for her ability to *understand the importance of controls, write a scientific report, think independently, use mathematics and computational thinking, construct explanations* and *engage in argument from evidence* increased from pre- to mid-surveys but were the same in the mid- and post-surveys (her rating was 4=quite a bit). Linda also thought that Ivette improved in these practices. For instance, regarding Ivette's ability to *think independently,* Linda said, "She learned a lot and she is already thinking what to do next, what are the experiments, and what experiments to do in the classroom". Similarly, for Ivette's ability to *construct explanations*, Linda stated:

> "Based on the discussions and the poster presentation that she presented she tried to explain what we were seeing and why we were seeing those differences, or in our case not much difference".

Linda gave us her views about Ivette's improvement in *engaging in argument from evidence* "...I think she is more than able to engage in an argument with someone about what was she found and what she knows". Ivette emphasized that the weekly research group meetings that she participated in helped her to understand how to *engage in argument from evidence*. She explained that, as follows:

> "We had a meeting like every week on Mondays. It depends on the commitments the professor had but I noticed everybody reports their own results or whatever they were doing in that week. The argument is a healthy argument for the common purpose of the research, that is something I really liked because you do not see that all the time."

Here, again we see the role of weekly research group meetings and the interactions that Ivette had with the group members including the professor, which is an important aspect of tightly structured research group.

Overall, based on the differences between the pre and post ratings in PST and graduate student surveys, the explanations in the interviews, and our observations (the criteria in **Table**

Table 3. The science practices Ivette improved a lot, a little less, very little, and not at all

	A lot	A little less	Very little	Not at all
Understand fundamental concepts		X		
Make use of the primary research literature			X	
Identify a specific question for investigation		X		
Formulate a research hypothesis			X	
Design an experiment	X			
Understand importance of controls		X		
Make observations and collect data	X			
Analyzing data		X		
Interpreting the data	X			
Reformulate the original hypothesis				X
Relate the research to the bigger picture		X		
Orally communicate the results of research	X			
Write a scientific report		X		
Think independently		X		
Develop and use models		X		
Use mathematics	X			
Construct explanations		X		
Engage in argument	X			

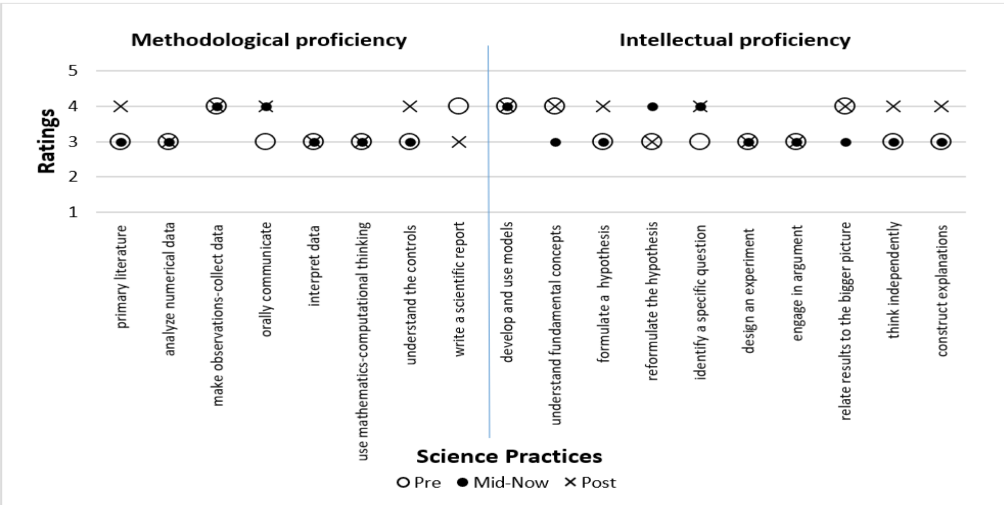

Figure 4. Ashlynn's self-reported pre-, mid-, and post-survey ratings of her abilities to engage in science practices (1-Not at all, 2-Very little, 3-Somewhat, 4-Quite a bit, and 5-A great deal)

2) we can say that in most of the science practices Ivette improved a lot or a little less. In two practices, she improved very little and in only one practice, we did not see any improvement (Table 3).

When we asked Ivette what the reasons for her improvements in the program might be overall, she emphasized the support and the guidance that she got from her research group were the most important reasons. She explained this, as follows:

> "One of the things that I believe that it helped me a lot is I worked with a really good team. 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 that I had in 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."

Ivette's also noted that participation in the research group enabled her to feel she was very important in the overall project. She expressed her responsibility and ownership as below:

> "To some point, I was feeling like I was an important part of it, whatever I was doing I have to be very careful, be very attentive so do not make a lot of mistakes because whatever I do it is goanna be part of something bigger and it help you to be more cooperative, it creates that responsibility, and it makes you feel good in that aspect…"

Ivette's explanations above indicate she felt she was an important part of a good team, she got support and guidance from the group members whenever needed, which suggests again she was part of a tightly structured research group.

Ashlynn

Ashlynn's self-ratings indicated that her ability to make use of the primary scientific research literature, formulate a

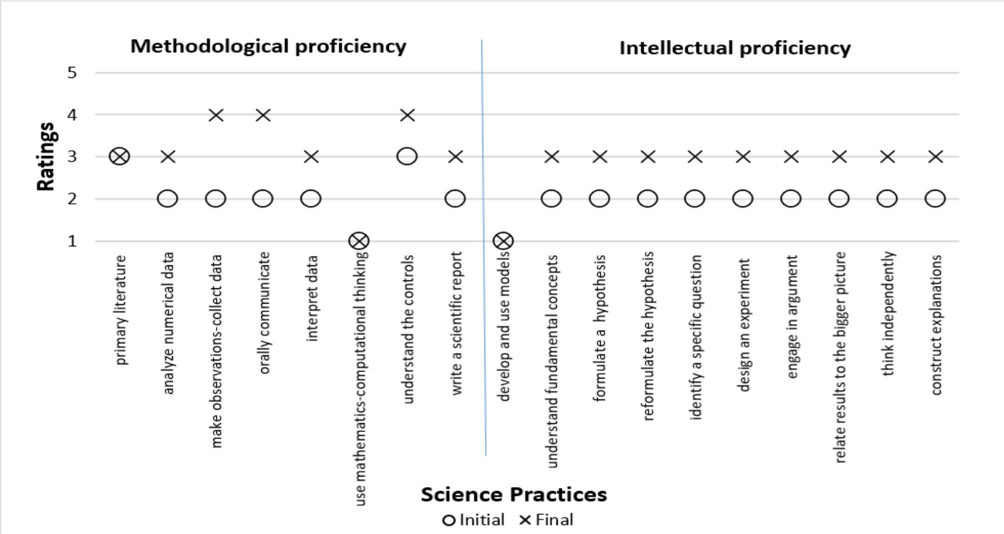

Figure 5. Graduate student's ratings of Ashlynn's abilities to engage in science practices (1-Not at all, 2-Very little, 3-Somewhat, 4-Quite a bit, and 5-A great deal)

research hypothesis, think independently, orally communicate the results of the research, and construct explanations stayed the same from the beginning to the middle of the program, but increased at the end (**Figure 4**).

According to her graduate student mentor, Sally, Ashlynn improved very little in these practices (**Figure 5**). She also confirmed this in her interview. For instance, she told us "I think that it is probably she got a little bit more experience doing research over the summer, but I would not be confident to say she was excellent at that."

For *thinking independently* practice Sally told us, "I think that Ashlynn could think independently but I do not think we really practiced that, so I did not really see very much improvement in that." Similarly, she stated the following about Ashlynn's ability to *construct explanations*:

> "I think that she probably could explain the nitrogen cycle on a basic level to students. I mean I think she did not know much about it before and sort of could do it better now."

Orally communicating the results of the research had the highest ratings from both Ashlynn and Sally, and was one of the two practices that she improved the most in. Sally explained that as follows: "I think that she did a good job or communicating the results from making the poster". However, she added "I think she understands what was going on and communicated it, but I do not know she necessarily grasped all the details."

Although Ashlynn's self-ratings indicated improvement in her ability to *make use of the primary research literature*, Sally thought that Ashlynn did not show improvement on that practice:

> "I did not really work with them [Ashlynn and Pat] 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."

When we asked Ashlynn whether she did a literature review, her answer supported Sally's explanation:

> "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 another research that was out there about aquaponics…"

Here, we see an aspect of loosely structured research group; Ashlynn did not get much support from her mentor for her ability to make use of the primary research literature. In addition, she did not have the opportunity to interact with others around the literature, like Ivette did in Sarah's group.

Ashlynn and Sally's ratings indicated there was a little improvement in her ability to *identify a specific question for investigation*. In our lab observations, when we asked her what question she and Pat were trying to answer, she was not sure and turned to Pat, the other RET teacher, for help. Also, in the interview, she could not clearly state her question:

> "I am not gonna 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 wastes in it and getting the nitrogen cycle working properly in an effective way. This is a really long question; I do not really remember exactly what it is."

Ashlynn's self-ratings in the pre- and post-surveys indicated that she thought her abilities to *understand fundamental concepts, design an experiment, make observations, and collect data, analyze numerical data, interpret data, reformulate a hypothesis, bigger picture*, *write scientific report,* and *engaging in argument from evidence* did not improve from the beginning to the end of the program (**Figure 5**). Sally's ratings showed that Ashlynn improved little in these practices except for *making observations and collecting data*. In the interview, Sally confirmed that while Ashlynn improved in *making observations and collecting data,* she did not show many improvements on the other practices. Sally said that Ashlynn "… was very able to collect the data and she got a lot of practice in the lab…". However, for *understand fundamental concepts,* Sally told us:

> "I do not think [Ashlynn] necessary picked up fully the concepts behind the nitrogen cycle so that is why I said somewhat. I think she understood it more but what we did she did not necessarily demonstrate a clear understanding".

Similarly, she stated the following for Ashlynn's ability to *write a scientific report* and *relate the research to the bigger picture*:

> "Ashlynn was very much task oriented, so *getting to the bigger picture* was not really something that happened with her. … *Writing a scientific report*, they did not have to write a scientific report, so I do not think that the skills improved much in that area to the teachers."

Although Ashlynn did an experiment for her research in the program, she did not show much improvement in *designing an experiment*. This may be because she was not given the opportunity to do so. Rather, when we observed her in the lab, we saw she was given a step-by-step procedure for the experimental methods. Sally confirmed this in her interview:

> "They [Ashlynn and the in-service teacher Pat] 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 interview also indicated that she did not *design an experiment* because she was doing what Sally told her to do. When we asked her about this, she responded:

> "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 aquaponics system. So, I guess, I mean, Sally had her project and then from that we could kind of do anything related to water quality…"

Similarly, although her research included data analysis, Ashlynn did not improve on *analyzing and interpreting the data*. The reasons for this became clear in our interview:

> "So, there is, me and the other teacher, we're 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… I feel like I would need a lot of help."

As we saw above, Ashlynn was reluctant to engage in data analysis. Her mentor allowed her to pass on doing it, instead of providing encouragement and scaffolding, which could have led to growth in this practice. Ashlynn's not learning how to design an experiment and her being able to remove herself from data analysis may have been related to a lack of mentoring skills by Sally. In a tightly structured group, she may have been able to discuss these issues with her mentor, but because Mia was away for the summer, there was not an opportunity for this.

For *engaging in argument from evidence*, both Ashlynn and Sally thought she did not improve on that practice. Sally explained that as:

> "She knows more about the nitrogen cycle now, but I do not think that she can necessarily engage in argument with someone, with a scientist that has a strong background in environmental engineering…"

Ashlynn's lowest abilities and which had no improvements in the program were to *develop and use models* and *use mathematics and computational thinking*. Sally explained that Ashlynn and Pat did not get experience doing either because her "research did not include models" and did not involve mathematical and computational thinking. Although this was not a focus of our research, Sally's response suggests that she had a naïve understanding of these two practices.

Sally's explanations about Ashlynn's abilities to *formulate a research question* and *think independently* indicated that the PSTs working with her were not given much responsibility in the project. For example, she told us:

> "*Formulate a research question*, it was not really something that I had them to do, most of the work they did was kind of hand given to them, so they did not have to develop their own question."

Here, Sally again stated the aspect of loosely structured research group that has limited support and interaction between the group members.

Overall, based on the differences between the pre and post ratings in PST and graduate student surveys, the explanations in the interviews, and our observations (criteria in **Table 2**) we can say that in only two practices Ashlynn improved a lot. In most of the science practices, Ashlynn either improved very little or did not show any improvement (**Table 4**).

When we asked Ashlynn, why she thought she had not improved much in the program, which she made clear through her survey response, she stated her research was guided mostly by Sally, so she did not take the responsibility of her research. She explained that:

> "I think that some parts of the research were done for us, so it was not necessarily for us coming up with everything on our own. The research in the project was really guided by the graduate student."

DISCUSSION AND CONCLUSION

In this study, we sought to understand how participating in loosely or tightly structured research groups influences PSTs' abilities to engage in science practices. In order to do that we focused on the experiences of two preservice science teachers, Ivette and Ashlynn in two very differently structured research groups. Above we explained why we categorized Sarah's research group as tightly structured and Mia's as loosely structured (at least for that summer when she was away from campus). Then, by focusing on the experiences that the PSTs

Table 4. The science practices Ashlynn improved a lot, a little less, very little, and not at all

	A lot	A little less	Very little	Not at all
Understand fundamental concepts			X	
Make use of the primary research literature				X
Identify a specific question for investigation			X	
Formulate a research hypothesis			X	
Design an experiment			X	
Understand importance of controls		X		
Make observations and collect data	X			
Analyzing data				X
Interpreting the data				X
Reformulate the original hypothesis			X	
Relate the research to the bigger picture			X	
Orally communicate the results of research	X			
Write a scientific report			X	
Think independently			X	
Develop and use models				X
Use mathematics				X
Construct explanations			X	
Engage in argument				X

had in their tightly or loosely structured research group, we make connections between the PSTs' improvements in their abilities to engage in science practices and the structure of their groups.

Ivette had very limited experience doing research before she participated in the RET program, and, not unexpectedly, our data analysis indicates that her abilities to engage in science practices were low at the beginning of the program. This suggests that she was a novice researcher at the beginning of the RET program. Our data analysis shows she made strong improvements on practices related to both methodological proficiency and intellectual proficiency. This suggests, she has moved along the continuum of roles in research groups from novice researcher to proficient technician and in some ways, gaining some of the knowledge and skills that we attribute to knowledge producers (see **Table 1**).

We categorized Ashlynn as a novice researcher at the beginning of the RET program because her self-ratings and the ratings made by Sally indicated that her abilities to engage in science practices were low. This was the case even though she had told us she had previous research experience. Our data analysis indicated that Ashlynn gained methodological proficiency, and that by the end of the program she was more able to engage in those practices, but still not at the highest levels. These are also the practices that others have reported teachers developing through participation in similar short-term research experiences (e.g., Lotter et al., 2007; Lunsford et al., 2007; Westerlund et al., 2002). Ashlynn had little improvement in the science practices related to intellectual proficiency. Therefore, this leads us to categorize her as a novice researcher at the end of the program.

Our findings suggest that much of the difference in outcomes between Ivette and Ashlynn can be attributed to the differences between their experiences in the research groups. Ivette participated in Sarah's tightly structured research group. The interactions between Ivette and Linda, her graduate student mentor, were facilitated by the way that the professor, Sarah, structured her research group. Ivette participated in the weekly research group meetings in which they discussed their research, and the students gave presentations about their research. This led to interactions not only between Ivette and Linda, but also with the other graduate students, Sarah, and another RET teacher who worked with one of Sarah's other graduate students. As a result, Ivette could benefit from being in frequent contact with students who were at different places along the continuum of research group roles, as well as regularly with Sarah, a highly respected knowledge producer in her field (Feldman et al., 2013). Also, Ivette and Linda discussed their research on a daily basis. Having these types of interactions is much less likely for the participants in loosely structured research groups (Feldman et al., 2013). In Ivette's case, however, the tightly organized and well-structured research group model that had collaborative mentoring increased training, experience, and scientific output (Elizondo-Omaña et al., 2019).

Ashlynn experienced a loosely structured research group (Feldman et al., 2009), in she had infrequent contact with Mia and with advanced students other than Sally. She engaged in the research activities with Sally, and they helped each other to complete their projects. However, the work that she did, while legitimate, remained peripheral as she engaged in the relatively low-level tasks given to her by Sally.

The above suggests that in tightly structured research groups, through scaffolding and feedback of the professor and graduate student mentor, Ivette's participation was legitimate and became less peripheral as the summer progressed. In addition, her frequent interactions with the other students in Sarah's group in the lab and in-group meetings enabled Ivette to improve her abilities to engage in science practices by having multiple learning opportunities. Ivette's participation in tightly structured research group allowed her to be a member of a scientific community of practice that included peer-mentoring, communications, teamwork, and community learning (Kobulnicky & Dale, 2016). Ashlynn's experience was very different. Instead of the scaffolding that Ivette received that moved her along the continuum of roles, Ashlynn was given step-by-step instructions from the graduate student about how to engage in research practices. Therefore, Ashlynn grew little in her abilities to engage in the practices of science.

Our findings also suggest that participating in the tightly structured research group enabled Ivette to better understand the expectations of the group and feel the responsibility of her part in the research. From the beginning to the end of the program, Sarah and Linda urged Ivette to take the responsibility for her research by pushing her to engage in high-level tasks, which helped her to develop both methodological and intellectual proficiency. Scientists' behavior plays an important role in building a trusting and collegial relationship (Valente et al., 2018). Sarah and Linda's behavior and relationship with Ivette helped her to feel more comfortable and take the responsibility of her research. On the other hand, in the loosely structured research group, Ashlynn was not expected to take on much responsibility for the doing of research because things were done for her, or she was directly guided by Sally. While much of this may be due to Sally's mentoring style, if Ashlynn had been able to interact regularly with the advanced graduate students and other RET teachers, she could have become aware of the types of experiences that she was not having and sought them out. In general, RET programs improve teachers' understanding of research process (Buxner, 2014; Klein, 2009) and their' functionality as scientists (Faber et al., 2014). However, as a result of Ashlynn's participation in a loosely structured research group, she was able to gain only some methodological proficiency and little of intellectual proficiency needed to research independently. Therefore, she left the group as a novice researcher.

Implications and Recommendations

Our analysis indicated that the experiences these two PSTs had in their research groups were very important in terms of the changes in their abilities to engage in science practices. One explanation from our data analysis is that the interactions between the graduate students and the PSTs are very important to improve PSTs' abilities to engage in science practices. These experiences, however, can be very different depending on the graduate student, the structure of the research group, and the PST. The findings also suggest that the support of the mentors is very crucial to improve PSTs' abilities to engage in the science practices. Of course, the PST is not a passive participant. As we noted, there were practices that Ashlynn was not interested in, such as the mathematical analysis of data.

In addition, participating in the activities of tightly structured groups provides opportunities to engage with other researchers with varying amounts of methodological and intellectual proficiency. On the other hand, participation in loosely structured groups does not provide those opportunities, and so novice researchers have fewer opportunities to learn from more advanced participants. Overall, our study suggests that the structure of the research group and its activities play an important role in providing PSTs with the experiences of science practices that can lead to intellectual proficiency.

The *framework* (NRC, 2012) and the NGSS (NGSS Lead States, 2013) call for teachers to be able to prepare their students so that they can engage in the practices of science. Unfortunately, few science teachers have had the opportunity to learn how to do science. In our study, we compared the experiences of two different PSTs who participated in an NSF-funded research experience for teachers program. In many ways, what Ashlynn experienced was typical of the short-term experiences that are described in the research literature. While they have many positive benefits, there is little evidence that they prepare PSTs to be able to engage in the science practices in the ways that the framework (NRC, 2012) or the NGSS (NGSS Lead States, 2013) expect of high school seniors. What we found is that if the research experience takes place in a tightly structured research group and the PST's mentor provides the opportunities to engage in high level science practices, then it is possible for preservice science teachers to emerge from a short-term research experience well on the way to having the types of methodological and intellectual proficiencies needed for them to prepare their students to engage in the practices of science.

It is also likely personal characteristics of the group members could influence the structure of the group (Feldman et al., 2013). However, the lack of data about graduate students' and PSTs' attitudes and personal characteristics is a limitation of the study. Our goal here is not to demonstrate causality between Ivette's and Ashlynn's experiences, but rather to illustrate how the different experiences and the ways that they were structured can affect the learning of how to do science. While personal characteristics may affect how professors structure their groups, what is important is the actual structure and interactions within the groups. This could be a topic for further research.

Our findings have implications for both science teacher educators and science education researchers. First, it is possible to improve PSTs' science practices through their participation in research experiences, which is promising for those in the field of science education. In this process, science teacher educators in particular should design or make use of research opportunities that are tightly structured groups so that PSTs have the opportunities to engage with other researchers with varying amounts of methodological and intellectual proficiencies. In addition, science teacher educators need to pay attention to the role of the mentors because they are essential to PSTs' legitimate engagement in the practices. Most likely, the mentors will need to receive some training in how to provide scaffolding instead of directing the PSTs in the research process. In this way, the research experiences would avoid being task oriented or mentor driven.

We end by noting that few institutions have the resources to provide research experiences for all preservice science teachers, or for the practicing science teachers in their regions. Therefore, science teacher educators need to find ways to engage pre- and in-service teachers in experiences situations that are similar to but not as extensive as participation in the research groups of our colleagues in the sciences.

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