Phenomenology of Secondary Students' Experiences in Out-of-School Time Science Research

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Abstract

Out-of-school time (OST) science research can be an important part of a student's decision to pursue a career in STEM. This article reports on the findings from a transformative phenomenological study of what secondary students experience while completing OST scientific research. The purpose of this study was to use an emic research lens to better understand the contexts and content of student experiences. We collected data from in-depth interviews with an ethnically diverse group of eight students who previously participated in science fairs, and five sponsors who supported science fair students. Major themes were found to be consistent through the student experiences, including opportunities to explore their own interests, deeply learn and apply science, and being supported by mentors and other professionals. The interplay of these themes seems to be critical to the experience as a whole. These findings hold implications for expanding out-of-school time science research opportunities for a more diverse group of learners.

Phenomenology of Pre-Collegiate Student Out-of-School Time Scientific Research

Science learning in the United States can take place via a variety of interactions, including through formal and informal contexts. Informal contexts have traditionally been described as "out-of-school time" (OST) science learning (Dabney et al., 2012). The opportunity to learn science through scientific research activities during out-of-school time has strong implications for the national STEM (Science, Technology, Engineering, and Math) pipeline – a proposed pathway from middle school, or earlier, to STEM interest in high school, collegiate education and entrance into the STEM workforce in the U.S. (NSTA, 2016; Committee on STEM Education, 2018; National Research Council, 2012). While the current debate on whether the U.S. education system is fostering enough STEM talent may not be settled (Freeman, 2008; Lowell & Salzman, 2007; Xue & Larson, 2015), there is general agreement that STEM jobs workforce demand will continue to see substantial growth in the U.S. and abroad in the near future (Carnevale et al., 2011; European Commission, 2007; Munce et al., 2012).

Research suggests that engaging in the science and engineering practices that are required to complete scientific investigations can be beneficial to a diverse range of learners (Lee, Miller, & Januszyk, 2015; Schwarz, Passmore, & Reiser, 2017). Increasing the diversity of learners engaging in STEM opportunities early in the educational pipeline could yield powerful results for our economy (Carnevale et al., 2011; Meador, 2018; National Science & Technology Council and Committee on STEM education, 2018), especially if we can increase access, achievement and retention via OST experiences (Lee, 2006).

The purpose of this study was to develop an in-depth understanding of what adolescent students experience when they learn science through OST activities such as scientific research. Our focus here will be on student experiences gained via science fair participation. While there is a broad range of OST activities that might carry a STEM focus, science fairs were selected because they are a very common OST context where middle- and high school students design and carry out their own STEM focused research projects.

A transcendental phenomenology approach (Moustakas, 1994) helped us gain understanding of contexts and structures of students' experiences and we can use this to guide the expansion of these learning possibilities so that we can include more students, especially those learners who have not been included in opportunities to learn science in this way. This valuable perspective has been absent from much of the research done on science learning through OST science experiences. Furthermore, as heterogeneity of students

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included in the category of "minority ethnic groups" is too great to be considered a homogenous group (Wong, 2016), individual perspectives become even more important when examining student experiences in research. Our approach will expand extant investigations of OST scientific research and, especially, the potential impacts of science fair participation (Kook et al., 2020).

Literature Review

Research evidence suggests that after-school education complements school-day learning by helping students build skills, improve overall attitudes towards learning, and raise their intentions to pursue higher education, all of which may contribute to enhanced student performance (Dabney et al., 2012; Lin & Schunn, 2016; MacLeish et al., 2012). Science learning that takes place outside of school time may include formal activities such as after school science clubs, semi-formal visits to zoos, science centers, nature programs (Lin & Schunn, 2016) and, of course, science fairs. Qualitative findings indicate that after-school programs are useful for developing science fair research ideas (MacLeish et al., 2012), although it remains difficult to recruit students to participate in these opportunities. Insight into the informal learning context of robotics camps, for example, highlighted the potential for powerful OST learning experiences because "the influence of the informal educator was more potent than that of peers or family" (Nugent et al., 2015, p. 1069). Additionally, some findings from quantitative studies suggest that educators should try to add activities to classroom learning that have an out-of-school component and that these experiences make it more likely that students create greater connections to curriculum content and issues of personal relevance (Vennix, den Brok, & Taconis, 2018).

Some evidence suggests that science fairs fulfill an important function by initiating learning processes through OST experiences (Paul, Lederman, & Groß, 2016). Paul and colleagues explained that inquiry learning through the completion of scientific research is an effective way for students to learn experimentation skills.

Traditionally, a goal of OST activities has been to develop STEM interest in students (Dabney et al., 2012). STEM interest is a central factor because research evidence suggests that interest plays a key role in the pursuit of STEM-related educational activities and outcomes. The combination of interest and self-efficacy are, for example, indicated as necessary for active STEM fair participation (Dionne et al., 2012). Interest is also particularly influential in the development of greater self-efficacy and more positive career expectancies (Nugent et al., 2015). STEM degree enrollment, in turn, has also been shown to be influenced by level of interest (Maltese & Tai, 2011). Evidence supporting science fair as a context that fosters initial STEM interest has, however, been inconsistent, and some findings (e.g., Maltese, Melki & Wiebke, 2014) suggest that science fair may not be a common pathway for fostering interest.

Despite a lack of consistent evidence showing strong links to initial STEM interest (vs. longer term engagement),we feel it is likely that science fair develops opportunities to initiate STEM learning that should be capitalized for strengthening STEM education and supporting career development (Sahin, 2013). Students' scientific research experiences and science fair participation tend to show a range of key benefits, not only to the individual researcher, but also to the future STEM workforce. These benefits include enhanced student learning outcomes as well as strengthening the STEM pipeline through increased student interest, an increase in student ability, and the retention of individuals from historically underrepresented groups (Sahin, 2013). Data from the National Education Longitudinal Study of 1988, for example, indicate that roughly only 50% of students who indicated STEM-related career interest (based on 8th grade expectations and math achievement) followed through on their science career interest (Tai et al., 2006). Keeping learners more engaged through OST scientific research experiences thus has the potential to impact STEM career training and participation.

Schmidt and Kelter (2017) presented evidence showing that student participants of science fair reported an enjoyment in experimentation and in presenting their research, and students also self-reported an increase in their science content knowledge. Nugent et al. (2015) note that student research experiences traditionally make space for student interest and student learning – strategies that educators can harness to increase learning outcomes for their learners. In a citizen science program, which allowed participants to experiences parts of the scientific research process, Lynch et al., (2018) found that participants, while already having a high affinity for science and the natural world, perceived increases in their attitudes towards entomology, nature relatedness, and science self-efficacy.

Other benefits of student science research experiences include keeping students interested in STEM fields as they move into post-secondary education, which will help strengthen the STEM pipeline (MacLeish et al., 2012). Several studies have examined relationships between students who participate in science research, and their interest in STEM education and careers. Dabney et al. (2012), for example, found that university and career interest in STEM were correlated with student participation in OST activity as well as middle school interest in science and math. Evidence from an additional study also provided support for our contention that student participation in STEM fairs is important and showed that science fair participation was a significant predictor of choice of STEM major in post-secondary education (Sahin, 2013).

Research also shows support for the idea that participation in STEM clubs may be a particularly important support for students from underrepresented groups. When combined with classmate/peer/tutor support and educator cooperation, club participation was found to be a central factor in STEM degree completions (Meador, 2018). Sahin's (2103) findings, cited above, showing that science fair competition predicted STEM major selection in college, was also gathered from a group where Hispanic students were well represented (47% Hispanic). Socioeconomic status is also a consistent predictor of STEM/STEMM (STEM + medical occupations) career plans at the undergraduate level, across nearly all subgroups, except Hispanic males (Dabney, Chakraverty, & Tai, 2013; Gottlieb, 2018). These studies showed that low-SES groups were frequently left out of STEM education. Leveraging after-school learning opportunities to engage students from diverse cultures is an opportunity that should be supported. These OST experiences can be more flexible and less formal than standard school-day activities, and might be more available to learners from a wider range of SES levels and ethnic/cultural backgrounds (MacLeish et al., 2012). While increasing student engagement in STEM is important to the enrollment of low-SES and minority students into the STEM pipeline, we should also consider public and educational policy (Dabney et al., 2012) and the emotional costs associated with technology use (Wong, 2016), in order to best develop inclusive STEM educational practices.

Finally, consistent evidence supports the idea that STEM interest starts early and an important window for engagement likely comes before the middle-level years (Dabney et al., 2012, 2013; Maltese & Tai, 2011; Tai et al., 2006). Informal exposure to STEM activities, such as free-choice learning opportunities (Falk et al., 2007; Rennie et al., 2003; Sha et al., 2015), were shown to be significant experiences for STEM undergraduate-degree holders across 70 colleges in 30 states (Maltese et al., 2014). Large data sets from the Trends in International Mathematics and Science Study (TIMSS) show that over 60% of the sample of fourth grade students (male and female; white, black, and Hispanic) reported strongly enjoying science (Riegle-Crumb et al., 2011). These results are encouraging for concerns regarding equity and access to STEM education, but they also highlight the need for more research investigating the experiences of middle- and high school students. The ability to support adolescent students, for whom school engagement often declines (Wang & Eccles, 2012), could prevent some further loss of learners from the STEM pipeline.

In summary, this review of current research evidence suggests that students may experience a wide range of benefits from engaging in OST scientific research processes, including skill-building, support for the development of interest in STEM as a career, and retention in STEM trajectories for minority and low-SES students, including positive effects on these trajectories for minority and low-SES students. Our current investigation will further explore the lived experiences of adolescent OST learners as they participate in science fair activities. Our interviews will also include students' mentors/sponsors, both because evidence suggests that mentors play a key role in supporting students' STEM interest (e.g., Pluth, Boettcher, Nazine, Greenway & Hartle, 2015), but also as a way to triangulate and confirm evidence we will gather from the students themselves. This investigation of these experiences will provide much-needed depth to our understanding of the potential effects of OST STEM experiences on the interest of actual participants.

Purpose

The purpose of this study was to use qualitative interviews and data to explore the student experience, from their perspective, of OST science fair research and the potential impact on their thinking about STEM related outcomes. For this project, we focused on middle and high school students participating in science fairs as a common example of an OST context in the U.S. where adolescent students can design, conduct, and present STEM-focused research projects (Avraamidou & Evagorou, 2007; Reis et al., 2015). Our student participants reported that they were responsible for developing their own research questions, study designs, and presentations.

A qualitative approach focusing on student perceptions of this phenomenon has the potential to provide more insight into the student experience than more traditional forms of quantitative-based research (Creswell & Poth, 2018).

Researcher Positioning and Reflexivity

The authors of this paper have experienced science fairs as participants, judges, as science fair committee members, and also have supported students with their entrances into science fair. (i.e., research project mentors) for student participants. We engaged in bracketing our experiences to develop **epoche'** (Moustakas, 1994), the setting aside of pre-judgements. We found this process was helpful to allow us a certain newness to the phenomenon, but we also recognize our influence in the research as developers of the research and interview questions, and of co-constructing meaning as the interviewers and data analyzers.

Central Research Question

How do students perceive the phenomenon of STEM learning through scientific research done outside the classroom?

Methods

Our methodological framework followed transcendental phenomenology (Moustakas, 1994) which positions us to gain an understanding of what students experienced, and how they experienced OST scientific research. As Moerer-Urdahl & Creswell state "Transcendental phenomenology…provides a systemic approach to analyzing data about lived experiences" (2004, p.32). A particular strength of this approach is the use of an emic research lens (viewing the research problem from the perspective of those who experienced it) to view the participants' descriptions of the phenomenon. This approach influenced how interview questions were designed (data collection) and how the data were analyzed, which are further discussed in the following paragraphs.

Sample Selection Criteria

Participants were selected based upon their shared experiences of having at least two recent entrances (within three years) into an annual metropolitan area science and engineering fair. Multiple entrances and recent engagement in science fair helped to ensure that study participants were close to their experiences and would have ample experiences from which to draw. Students with multiple experiences have an expanded worldview of conducting science research for science fair compared to participants who may have had a singular experience. Sampling methods included convenience sampling through partnership with a local science fair for the sampling pool, and maximum variation of the sample by selecting participants who varied across demographic markers. The science and engineering fair IRB approved our request for research participants and worked with us to contact participants. We obtained parental and participant informed consent per institutional IRB guidelines. Our final pool of participants included: students who identified as male (2), and female (6); high school freshman (1), juniors (3), and college freshman (2) and sophomores (2); African American (4), Caucasian (2), Latinx (1), and Indian (1). Additionally, seven of the eight interviewees had participated at the state science fair level, five of whom presented at the American Junior Academy of Sciences in connection with AAAS. Five educators who had previously sponsored students to enter a science fair, or "sponsors", were also selected to be interviewed.

Data Collection

We collected data through two interviews per participant, of up to 30 minutes each. Interview questions (Appendix A) aimed to discover *what students experienced*, and *how they experienced it* (Moustakas, 1994). participants were initially asked about science research experiences in the setting of a classroom, and then about OST experiences. These questions were designed to help participants access specifics of their experiences that aligned and contrasted between the two settings. Additionally, the phenomenological approach allowed our question design to focus on what the experiences of those who participated in this phenomenon. Two of the authors each interviewed four different student participants and 2-3 sponsors at public libraries near a location of the participant's choosing. Interviews were audio recorded.

Data Analysis

Interview recordings were transcribed using automated transcription software, and then were de-identified to maintain confidentiality. Transcriptions were coded in MAXQDA by the authors, using Moustakas' procedure of identifying significant statements, horizonalization (1994), with each statement being treated equally in regard to its importance to the study. We then chose themes based on significant statements that add to the textural meaning of the experience by making code maps in MAXQDA. Themes were further developed by the authors based upon participant experiences. Finally, a unified statement which captures the essence of the experience was derived from the textural and structural descriptions of the themes.

Validity, Reliability, and Transferability

Achieving internal validity can be one of the strengths of qualitative research, (Creswell & Poth, 2018; Merriam & Tisdell, 2016), and triangulation that includes member checks, researcher positioning, peer review, and engagement in data collection will bolster internal validity (Creswell & Miller, 2000). Triangulation occurred as we used the same interview protocol for five educators who have sponsored science fair students. Data from their interviews further supported what our student participants experienced, as stated in our findings section. Member-checking was conducted after initial data analysis to strengthen internal validity. Participants were asked to view code maps around each theme, and then to make comments about our suggested themes. Responses from the participants and sponsors are discussed along with our findings.

Reliability and transferability are treated differently in qualitative research compared to quantitative studies because of the unique nature of qualitative research that demands different criteria of evaluation which often falls under the umbrella of trustworthiness (Lincoln & Guba, 1985). In qualitative research, researchers' goals are to elicit a detailed description of the studied phenomenon drawn from a typically small sample of participants who are vested in the phenomenon (Babchuk, Guetterman, & Garrett, 2017). Methods to ensure consistency between the researchers' explanations and study participants' views of the phenomenon (internal validity) include triangulation, peer examination, and the investigator's positioning (Merriam & Tisdell, 2016).

Findings

Analysis of data led us to identify four themes that were prevalent across all interviews: *Exploring Your Interests, Mentoring and Supporting Students, In-Depth Learning Through OST,* and *Seeing the Application of Science Processes and Content*. Each theme is described in detail below, and is supported by evidence statements from participant interviews. All names used are pseudonyms to protect the identity of research participants.

OST Science Research: Exploring Your Interests: Dana stated her excitement about the internal desire to do research, "I have an idea, can I investigate it?". For students, doing scientific research outside of school gave them the opportunity to investigate questions they had about the natural world. It also became, as Courtney stated, a "purpose to learn" and "being able to venture out on my own". Scientific experimentation was described as fun when participants were researching something that was personally interesting; satisfying to ask and be able to answer your own scientific questions, and also difficult when finding out how to come up with the answers.

Students also stated that they were able to answer their own questions and pursue interests which often exceeded school science curriculum. Ophelia describes the opportunities presented by doing research for science fair "are you interested in learning more about the world? Do you have a problem, issue, a question that you want answered?". Whether they had a cluster of ideas that seemed interesting to research, the chance to discover something yet-to-be discovered, or interests that stemmed from wanting to help others, students had the option to explore whatever they wanted to study. Students reported an opportunity to work towards personally relevant issues such as researching diseases that affected loved ones, as Aaliyah states "…kidneys have a large effect on the body. It affects your blood, the excretory system, and the endocrine system. And I knew all those things ahead of time and that's part of the reason why I got interested in it".

Nina described the cascade of research in comments such as "you answer one question. Then you get 20 more". At times, what was learned in the classroom initiated students' desire to further investigate outside of school, so the classroom content became a "steppingstone" for Marcus and for others. Oftentimes, their scientific questions were unable to be answered during the regular school day. Being able to have an interest in the work of the lab, and the researcher giving the student the option to ask their own research question, led to the student putting time into background research and developing something for Francisco that he says, "I feel passionate about".

Sponsors helped further define the theme of *Exploring Your Interest* where they wanted to support students exploring scientific interest outside of their classrooms, but expressed feelings of being constrained by the curriculum. Consider the posit of Jared, who was a sponsor, "…each student could be pursuing a different topic, which can't happen in a regular classroom when we're focused on a particular topic that meets a standard that has to be met for class." Jared went on to describe his position that he counted on the science fair as a way for students to have the opportunity to more fully be in charge of their research.

Anna, another sponsor, also offered evidence that her students conducting research were exploring their interests "the coolest part of it to me is that a lot of them continue that work after they have left us." In her estimation this was proof of intrinsic motivation that comes from the students exploring their own interests.

OST Science Research: Mentoring and Supporting Students: Students reported that mentors and a supporting cast, through their science research experiences, whether in the classroom or outside of the classroom were an important part of the experience. This support was acknowledged, appreciated, and they indicated that this sometimes led to making long-lasting connections outside of the classroom.

Students said they experienced teachers who stayed after school to work with them on their research projects. Students expressed being able to go to their teacher if they had any questions about their OST work or their coursework. Linsey explains reaching out for professional help "I ended up contacting someone again the next year for my monarch project...a couple of people who were associated with Monarch Watch…I also contacted Dr. Holdred at [university]…and participated in a butterfly count". Shadowing opportunities allowed students like Marcus to "get a glimpse and be a part of it" that helped to reaffirm choices in career choices.

Students typically experienced support in the form of having more resources and access to help with science research. Aaliyah notes that "we got to work with Dr. Bruggan at [research university], so we go to learn steps for taking samples to a lab, and different processes in the body, and then social elements…we sort of go to feel like real researchers". They experienced what Francisco described as "consistency in people who cared about me" throughout their OST learning experiences. Students stated that they appreciated the access to graduate students and undergrads when working in research labs. This was especially appreciated by students when they were in research settings as the only high-school student, such as Linsey who said "It's good to have people there to bounce ideas off of", and "she has a special way with the standard operating procedures, how we organize [data and research]…cause if that's how trained scientists know how to organize it then it's a good way that I want to do it". Also, students noted that when working in groups of similar aged students, learning was enhanced because students asked questions of each other and worked towards what Nina called "being on the same page" of the research experience.

The sponsors' data on *Mentoring and Supporting Students* revealed that they believed there was a certain fragility of students conducting out-of-school, scientific research such as that in science fairs. In relaying her experiences on students conducting research in, and out, of her classroom, Trina said, "I mean there is a lot of failure in science, and in the regular curriculum I think we kind of, we explore, but a lot of their explorations, are, um, fail proof." Trina was counting on students being able to experience failures in their out-of-school science research as a more authentic science research experience, but then felt that she needed to position herself to help her students understand that experiencing that type of failure was normal and to encourage the student researchers to continue with their work. This also supports what Francisco relayed in having sponsors who cared for and looked out for the student researchers.

Doug and Jared, student research sponsors, also found that providing students access to resources and equipment was an important part of *Mentoring and Supporting Students*. This is somewhat related to being a thought partner as Francesca describes in that the sponsors could help identify resources, tools, equipment, or even professionals from the field to help students with their research. Thus, providing support that could help a student keep from getting stuck in their research.

OST Science Research: In-Depth Learning Through OST: Students' perceived value of their classroom science learning experience in high school varied, but there was a strong sentiment that the learning of science while conducting their own research was at a deep level. The context was that "doing science" is all about solving problems that range from what to investigate, how to do the investigation, and how data can be analyzed and interpreted.

Aaliyah reported that "I remember the majority of it [uses for microbial fuel cells from research project] because I was so interested into it…still amazes me after the whole experiment that you could do that and produce electricity". Participants reported on the building of academic skills, and of skills in conducting scientific research, during OST. The content they reported about in-depth learning related to the research they were conducting, procedures of how to conduct scientific investigation while they researched, and their work required them to use problem solving to get through difficulties and to critically think about what and how to investigate.

Research participants reported learning statistics and mathematical concepts such as trigonometry, as needed for their research outside of the school building, before needing these skills in the classroom. Participants spoke about the problem solving often required when having to test questions to find answers about their research before they could test their main research question, such as Linsey who needed to "try out what size square of area I wanted to look at, and what different elevations I wanted to look at… we ended up getting a bendy [ruler] that was helpful in measuring the curvature of the moss and lichen in it [survey plot]. Learning took place in university research labs, about how to get usable saliva samples to be analyzed in the lab, in conjunction with learning neuroscience and sociology content. In all cases described, in-depth learning took place under the conditions of student choice of research topics and being active participants in developing and conducting their own investigation.

Doug, a student research sponsor, defined this phenomenon,

> I think that the individualized student research can go deeper, and you can go deeper and, and in angles that go beyond the scope of the classroom or in the classroom. There are some concepts because of the curriculum that you want to make sure a student understands for foundations for future grades. Um, but it provides an additional depth that you can't get in a classroom where you're limited by time and by curriculum. By having 25 to 30 students that are room [you're not going] to be able to get to that depth. So, yeah depth and being able to [explore] questions that may or may not seem related to the prescribed content.

Also consider the words of another sponsor, Trina:

> I think we can encourage them to pursue that further. Although I would say the curriculum is fairly full and we can't maybe spend weeks and weeks on it, you know, for one kid in the classroom. But I think it, it sparks interest and you know, teachers can encourage them…to follow up on it. I guess to follow up on their interests and we have a little bit of room, maybe to have a discussion or…have a discussion that is spurred by student interest or started by student interests. in the classroom. But I also think that at some point you have to just encourage them to pursue it outside.

Trina here is confirming Doug's point about letting students go deeper in their learning. This adds the nuance that student-led research, such as experienced in OST science fair research, provide access to more in-depth science learning than might be available in the science classroom. In the example above Aaliyah's enthusiasm for learning about microbial fuel cells provides her an in-depth learning experience.

OST Science Research: Seeing the Application of Science Processes and Content: When research participants conducted their own scientific research, they told us that they learned that science can be applied to various aspects of their lives and to the lives of others. Throughout the data collection, it became apparent that students felt their research had a role and/or played a purpose in society.

Participants reported needing to use skills and knowledge from other domains and apply them to their scientific research. Marcus says "I wanted to make my research more related to engineering" and "I decided to engineer my own enrichment toy, to help boost their [animal's] enrichment activity or their interest in it". Students took advantage of the opportunity to deeply investigate something that interested them, and during that experience they saw a relevancy in what they were doing.

Students reported experiencing local applications of their scientific research, such as water resources for their local municipality, or doing research on microbial fuel cells and discovering that they are also used to generate clean water on the international space station. Research led to investigations in solutions for cleaning massive oil spills, water purification techniques for cost analysis and potential to scale-up to be a solution for communities in need, finding ways to identify indicators of potential colony collapse disorder in beehives. Determining the most efficient and effective power sources for drones, as well testing the design of enrichment toys for mammals were also contexts.

In addition to *Applications of Science Process and Content* as described by Marcus and others above, Francisco added to this theme,

> I would definitely say that, for me, once exposed to good science teaching and good attention, you know, helpful instruction that I think definitely became more of a part of my thought process and how to approach scientific problems. And then how to use that knowledge to translate with other subjects and other classes. It was kind of the situation where I was into what was being taught you know, [then] contemplate it outside of class. Then, like I said before, apply what I had learned or tools I had learned with that [research project] and use it with my other classes to kind of always keep. It always kept me on my toes and just kept me thinking so that I was always kind of fresh and everything that I could.

In this data we see that Francisco is not only applying science process and content to other science learning experiences, but he is also showing that he is applying the scientific reasoning he learned while completing his research to other courses. In this interview, he went on to relay that his OST science research work prepared him to be able to handle the rigors of his first year of college, and that he expected to rely on his academic work ethic to support him throughout his college experience.

Though Francisco was not sponsored by Trina, his words should help reify her hopes for her student researchers, "Then hopefully they'll get to the problem solving, like, how can this be used in the real-world kind of thing." She felt that having the opportunity for students to speak about something they were knowledgeable, as in the science fair presentation process, would reduce fears of public speaking. In her interview she went on to say that she had to sometimes encourage students to "force themselves out of their own box."

While our findings here are separated into four themes, the phenomena of OST science research as related by our participants was more broadly, one unified experience. The four themes were intertwined and depended upon each other. Figure 1 shows that the overarching experience for these participants is inseparable from the four themes. For example, student researchers cited access to resources, being able to work in a university lab to test samples under the guidance of science teachers and research professionals as they investigated their topic of interest. This allowed students to let their curiosity drive the research, such as Sylvia, who was able to "discover the unknown". Through their discovery, they uncovered relevancy of their research in a unique and powerful way.

The Essence of the Experience

The essence of the experience of out-of-school time science research is that students experienced deep learning of science content and research processes when they were supported by educators, and science professionals, while being mentored through investigations of their design and their interests. In these instances, students came to realize the application of science content, which also impacted their in-school learning. For example, Linsey's research experiences in a biology lab over the summer capture the essence "Most of the students in [our summer program] …had a question given to them. They already had a methodology given to them…more like a lab technician [job]…My [research sponsor] said she would give me the option to work on something myself if I wanted to participate in science fair. I was able to find a question…I get to design my own research project". Linsey goes on further to describe scouring through research articles to learn about the biology of honeybees in order to test for possible markers of the health of a colony.

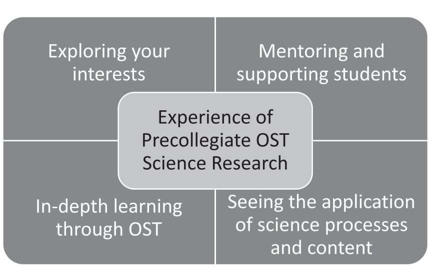

Figure 1. Illustration of Core Themes.

Although we were able to identify four unifying themes across participant experiences, there were a few noteworthy nuances among our participants related to these four themes, such as underlying motivations to engage in OST research. For example, we found the testimony of a female, non-Caucasian student, who participated to prove to her teachers and classmates that she could be successful at scientific research (and in academics). Her participation confirmed what she believed about herself and led to further successes. She says "[I] didn't get the opportunity to [do research], and I wasn't really considered a smart kid in middle school, and I really wasn't until I won science fair" and "I had gathered a lot of accolades, awards, and that spoke for me…I loved learning, I did not like the structure of the classroom".

This important, and underrepresented (in terms of race and gender) voice provides an interesting finding worthy of a follow up study because the novel response did not situate itself within the prevalent themes. This student showed a very high level of motivation to explore her interests and she made extensive use of mentors and available scaffolding. She showed in-depth learning about a topic and was able to see application of processes and content beyond her work with OST student research. Her motivation to engage with the research would have compelled her to undertake OST research on her own, regardless of available supports. In many regards, we understood how she felt as a self-described "pioneer among non-white, female OST student researchers". This information is important and evidences the presence of multiple discourses amongst individual participants but did not prevail as a theme across our data.

Discussion

Our review of the research literature underscored the importance of OST science activities, especially scientific research, for supporting increases in student competency with scientific content (Schmidt & Kelter, 2017) and developing skill in the processes of science (Paul et al. 2016). Our themes "in-depth learning through OST" and "seeing the application of science processes and content" align with these findings. We showed that there were significant implications for early STEM exposure (Dabney et al., 2013, 2012; Maltese & Tai, 2011; Tai et al., 2006) and the involvement in OST learning activities in helping maintain student interest in STEM fields over the long-term, especially for students who came from a minority or other underrepresented groups (Meador, 2018; Sahin, 2013). Results from this study are also consistent with our contention that the flexibility and potency of OST science learning activities should not be overlooked because they are an important STEM access point for those who may otherwise be shut out from STEM education (MacLeish et al., 2012). While other research linked participation in OST activities designed to STEM interest development, and later participation in scientific research and interest in STEM careers and degrees (Dabney et al., 2012; Sahin, 2013; Smith, 2013), we did not find clear support for that specific pathway here. However, this may be because the participants had already developed an interest in STEM prior to the study. We did find evidence that their experiences helped them build important skillsets and had a direct influence on their desire to further engage in STEM experiences.

Study participants reported increases in their science content knowledge, and in their skills in executing the process of science in the themes *In-Depth Learning Through OST* and *Seeing the Application of Science Processes and Content.* Participants learned through inquiry methods, and told us that they were engaged in the processes of science (*In-Depth Learning Through OST*) which supports findings that these types of experiences are indeed effective ways for students to learn experimentation (MacLeish et al., 2012; Paul et al., 2016; Schmidt & Kelter, 2017). In many cases, study participants gave detailed insight into how they benefited from their OST experiences in the academic classroom setting. This also mirrors findings from MacLeish et al. (2012) about the ability of OST learning to enhance students' school performance. Contrary to other findings, (Dabney et al., 2012; Sahin, 2013; Smith, 2013), our findings did not show a direct connection between OST learning and STEM-interest development. Rather, our participants reported already having a burning interest in a STEM topic and felt that they received strong, consistent support to engage with that topic and to investigate it further (*Exploring Your Interests).*

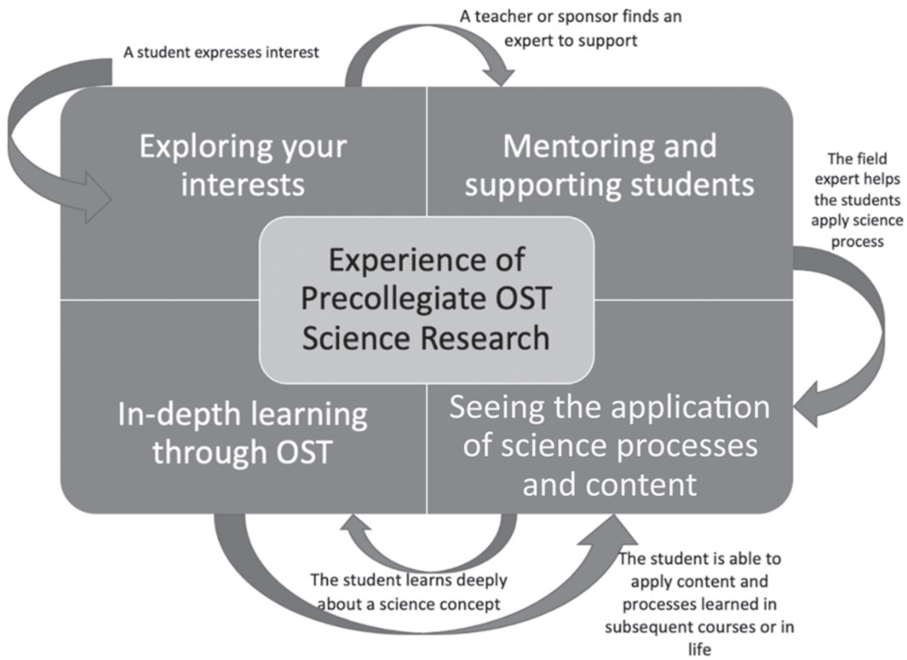

Figure 2. Possible Sequence of the Experience.

The theme *Mentoring and Supporting Students* illuminated the importance of teachers, science researchers, and professionals as mentors. This was consistent with research findings reported by Nugent et al. (2015) indicating that OST mentors can have a powerful influence on learners. According to our data, participants reported that mentors came in all of the forms listed above, and teachers took on a special mentoring role when learning through scientific research took place outside of the regular school day.

A theme suggesting that students became interested in STEM career pathways from conducting research did not emerge in our data. As noted above, our participants seemed to already have great interest in STEM pathways and were selected for this research after having conducted at least two science fair research projects that also seemed to align with their interests. Our interview questions were not designed to explicitly investigate the relationship between scientific research and student interests in STEM degrees and STEM careers as that aspect of the experience may require more longitudinal evidence to be gathered. Our study was also not designed to include longitudinal follow up, we would not have learned of STEM major or career interest if it developed later in their secondary education careers. These are, however, key areas that future studies and interviews need to address more directly.

While the phenomenological approach allowed us to deeply examine the scientific research experiences of a small group of students, the findings from this research are not representative of every student who experiences OST science fair research. The findings that we presented here are a thorough and detailed investigation of the experiences of one diverse group of secondary students and serve as a powerful example of the potential benefits of OST science fair research experiences for this group of students.

Implications and Future Research

The essence of the experience of out-of-school time science research emerged as students reported their experiences of deep learning of science content and research processes when they were supported by educators, and science professionals. This occurred while being mentored in investigations of their own design and motivated by their interests. Additionally, students reported that they were able to transfer several aspects of what they learned in other situations. Several of our themes could serve as entry points for further work into developing processes for supporting students conducting OST science research. For example, if teachers notice students' strong curiosity in a content

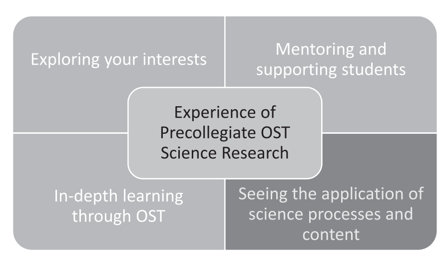

Figure 3. What is Still Unknown.

area, our students showed that being introduced to professionals, who could then help them to apply science processes to their interests and questions would likely facilitate deeper engagement and learning in STEM areas. Exposure to applied science could also spark the student in beginning a journey into scientific research as it did for Sylvia who said “it wasn’t something you saw on TV about the polar ice caps melting…you could actually see the difference in the melting of the ice [in your own experiment]”. Figure 2 shows this type of chronological sequence, tied to the study themes and developed from our participants’ reports of their experiences (starting at the top left and follow the arrows).

We also noticed the students reported a strong connection to science processes, see Figure 3, more formally labelled science and engineering practices (SEP’s) (National Research Council, 2012). For example, one entire theme, *Seeing the Application of Science Processes and Content,* showed strong connections to SEP’s. We see the link between OST science research experiences and applications of science and engineering practices as an invitation to: 1) help us better understand the experience of pre-collegiate student research and 2) also help us better understand the role of science and engineering practices within the science teaching and learning that goes on inside of the classroom. Further research detailing these processes across larger and more diverse groups is needed to better understand how we could foster science research skills and interests in both environments.

In looking at the sum of the experiences of our participants and the evidence that we presented here, we were greatly encouraged that this study so clearly showed the value of their OST science fair research experiences in supporting their STEM skill development and engagement. We felt that this was a strong indication that the development and support of these programs will benefit learners across broad variety of contexts and that this represents a worthwhile and effective use of education resources.

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