

Fostering Interest in and Motivation for STEM: An Illustrative Case Study of Middle Grade Students' Experiences in Out-of-School Time STEM Activities

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Abstract

Numerous STEM agencies and advocacy groups posit that Outside of (regular) School Time (OST) STEM opportunities spur middle school students' learning, especially in fostering students' interests in and motivations for STEM. The purpose of this study was to investigate the sources of students' interest in and motivation for STEM while participating in one or two OST STEM activities (i.e., SeaPerch, Science Olympiad, Girls Who Code, and/or eCYBERMISSION) at their independent (private) middle school. Using an illustrative experimental single case study design, data were sourced from observations, a questionnaire, and interviews from 15 middle school students participating in one (or two) 13- to 16-week OST STEM activities at their private school. Results suggest that sources of student interest and motivation related to OST STEM activities were mainly sourced (30% of data coded) from students' self-motivation and intrinsic interests in STEM. Other sources of student interest and motivation were from their teachers (20%), the enjoyment they derived from the OST activities (20%), support from family (10%), school friends (10%), and supportive persons outside of school (1%). Recommendations for strengthening participation in OST STEM activities as well as avenues for further research are discussed.

Keywords: Case Study; Interest; Middle School; Motivation; OST; STEM Education

Introduction

Prior research has shown that participation in structured Out of School (OST) STEM experiences is a key factor in enhancing students' interest in Science, Technology, Engineering, and Mathematics (STEM) disciplines (Afterschool Alliance, 2015; National Research Council [NRC], 2009; 2015) suggesting that OST STEM activities and programs improve students' access to STEM (NRC, 2009). These OST STEM activities offer authentic, hands-on learning with STEM tools (e.g., computers, 3D printing, probeware) and practices (e.g., 21st Century skills, the engineering design process) which have been shown to support students' learning of STEM content (International Technology and Engineering Education Association [ITEEA], 2016; Holmquist, 2014; Mohr-Schroeder et al., 2014; Nugent, Barker,

Grandgenett, & Adamchuk, 2010). Per the NRC (2009), unique to OST STEM activities are opportunities for students to learn STEM content differently than in formal K-12 STEM experiences (see Renninger, 2017), such as development of shared norms and practices and their attendance tends to revolve around participants' interests instead of compulsory mandates. Many OST STEM activities are facilitator guided but largely student directed with hands-on learning; this type of learning environment can help shape middle school students' interest towards STEM (Hayden, Ouyang, Scinski, Olszewski, & Bielefeldt, 2011; Mohr-Schroeder et al., 2014; Nugent et al., 2010). Though specific requirements vary by activity, OST STEM activities task students to work in groups such to tackle community-based problems by leveraging choice and voice of students (Lyon, Jafri, & St. Louis, 2012; Noam & Shah, 2014). Such activities manifest as challenge-based competitions where students must ideate (e.g. eCYBERMISSION) and create a working prototype (e.g. SeaPerch), collaborate on STEM-based projects (e.g. Girls Who Code), test their STEM knowledge and skills (e.g. Science Olympiad), among others. These activities require that students employ design thinking, engineering skills, and problem-solving, through hands-on learning with STEM tools and technologies. In sum, OST activities are defined in this paper as organized and sustained learning experiences where students acquire STEM content in informal (free-choice) to non-formal (more structured than informal) learning environments (NRC, 2010; 2015). In OST STEM activities, students are afforded a great deal of flexibility and choices, making STEM more appealing (Chun & Harris, 2011).

Research suggests that eighth grade aged students who participate in OST STEM activities, are more likely to express interests in pursuing STEM as their post-secondary education major (Chan, Choi, Hailu, Whitford, & Duplechain DeRouen, 2020) or have a career interest in STEM (Dabney et al., 2012). These findings may be explained, in part, by prior OST-based research which found that students who participated in OST STEM activities had reported those experiences to be influential in their STEM learning (Afterschool Alliance, 2015; Brown, 2016; NRC, 2015). Hence, research on OST STEM activities and their influence on the non-cognitive, affective outcomes for middle grade learners has grown as an extension of the ongoing research on the importance of formative STEM experiences for children and young adolescents (Archer, DeWitt, Osborne, Dillon, Willis, & Wong, 2010; 2012; Chesloff, 2013; McClure, 2017).

This study focused on middle school-aged students' interest in and motivation for STEM, centered around their participation in one or more established OST STEM activities: SeaPerch (2019), Science Olympiad (2019), Girls Who Code (2019), and/or eCYBERMISSION (2019), within an urban parochial school. Fifteen students were observed, surveyed, and interviewed to understand how their experiences in OST STEM activities influenced their interest and motivation towards STEM.

Framework

The framework of this research is rooted in the literature of STEM interest and motivation for middle grade (11 to 14 years of age) students. Interest and motivation were the selected constructs of study as students make choices to pursue or not pursue (engage or disengage in continued participation in) STEM in early adolescence (Christidou, 2011; Lindahl, 2007). Provided that informal STEM experiences support students' interests and motivation in future STEM endeavors (NRC 2009; 2015; Sahin, 2013), so should group-based OST STEM activities. These constructs are significant as both STEM interest and motivation are important aspects for future STEM persistence (e.g., studying STEM in high school, college, pursuing STEM careers) (Adams, Gupta, & Cotumaccio, 2014; Fayer, Lacey, & Watson, 2017; Simon, Aulls, Dedic, Hubbard, & Hall, 2015). For this reason, it is important to understand how affective factors (i.e., interest and motivation) are thought to influence students' affect towards STEM (Nugent et al., 2010; Makhmasi, Zaki, Barada, & Al-Hammadi, 2012; Maltese & Tai, 2011).

Fostering Students' Interest in STEM through OST STEM activities. Prior research has shown that OST STEM activities have been evidenced to improve students' science understandings (McNally, 2012), to form a STEM identity (Hughes, Nzekwe, & Molyneaux, 2013), and to shape one's knowledge, productivity, and learning (Eshach, 2007; Sullenger, 2006). Therefore, prior work suggests OST STEM activities may be a reform-based lever to improve STEM learning for students (Brown, 2016) by encouraging and reinforcing students' interests in STEM.

Fostering Students' Motivation in STEM through OST STEM activities. Like interest, motivation has been found to be a key factor in students' pursuit of STEM knowledge and skills (Bull et al., 2008; Schunk, Pintrich, & Meece, 2008; Wang, 2013). Motivation is influenced by one's beliefs, persistence, effort, and choice, all of which, when positive, are indicators of future academic success (Freeman, Alston, & Winborne, 2008; Lirmenbrink & Pintrich, 2002). When a student becomes interested in STEM, he or she becomes motivated to learn, whereby increasing their STEM learning (Boy, 2013). Motivation is supported through goal-based activities that encourage students (Schunk et al., 2008), especially activities that challenge learners (Schmidt, Beymer, Rosenberg, Naftzger, & Shumow, 2020) and develop personal autonomy (Earl, 2019). A hallmark of informal learning is a voluntary, open-ended, learner-driven environment, that nurtures students' interests in and motivation for STEM (Leblebicioglu et al., 2017; Stocklmayer, Rennie, & Gilbert, 2010).

The literature suggests that OST STEM may be a platform to foster students' motivations for STEM learning, and schools have joined other sites (e.g., community centers) to offer OST

STEM learning experiences for their students (Scott, 2012; White, 2014). Opportunities for collaboration and peer-to-peer interaction promote as a sense of belonging as students work towards a common goal, enhancing their motivation for STEM learning (Andersen & Ward, 2014; Freeman et al, 2008). As OST STEM activities largely rely upon this cooperative and goal-driven paradigm, OST STEM activities may also foster student motivation for STEM learning (Braund & Reiss, 2006; Krishnamurthi, Ballard, & Noam, 2014; Modi, Schoenberg, & Salmond, 2012; Tai, Qi Liu, Maltese, & Fan, 2006).

Purpose of the Study

The purpose of the study was to explore students' experiences within four established OST STEM activities and how aspects of those experiences (e.g. the persons they interacted with or entities that reinforced those experiences) played a role in participating students' reported motivations and interest in STEM. To visualize students' affective outcomes from participation in STEM OST activities, meaning in what ways students' STEM interest and motivation was stimulated through OST STEM activities, participating students were observed during OST STEM activities, sat for interviews, and responded to an open-ended questionnaire. This study is part of a larger research study that explored middle schoolers' STEM identity and persistence from participation in OST STEM activities (Taylor, 2019). This research sought to identify in what ways, if any, OST STEM activities fostered positive affect in interest and motivation for participating middle school students.

Research Question

In this case study, the following research question guided this study: what were sources of middle school students' interest in and motivation for STEM learning stemming from their participation (before to after) in at least one of four established OST STEM activities?

Methodology

An illustrative experimental single case study was conducted to answer the research question. The illustrative purpose of the case was to advance or bridge understanding of a topic which was students' interest in and motivation for STEM activities (Hayes, Kyer, & Weber, 2015) and an "experimental case study...to evaluate the potential benefits" (Scapens, 2004, p. 260) upon participating in OST STEM activities. Per Yin (2003), the case study approach is a preferred strategy when the researcher has little control over the events (in this case, the OST STEM activities) and focus is on the group of students participating in and benefitting from the intervention (in this case, their OST STEM experiences).

Context of the Case. Case study participants were 15 middle school students (seven girls and eight boys) who participated in OST STEM activities at the case location from the sixth ($n = 2$),

seventh ($n = 7$), and eighth ($n = 6$) grades, all of whom participated in one (or two) of four OST STEM activities at a K-12 independent (private) college preparatory school located in a major urban city within the Southeastern United States. Although some students participated in more than one OST STEM activity, seven students primarily participated in SeaPerch/robotics, five in Science Olympiad, two in eCYBERMISSION, and one student in Girls Who Code.

OST STEM Activities. Specific OST STEM activities, such as Girls Who Code, eCYBERMISSION, Science Olympiad, and SeaPerch, provide students the opportunity to pursue their specific STEM interests and content (Abernathy, & Vineyard, 2001; Brown, 2016). Therefore, these were the OST STEM activities of interest. At the case location, Girls Who Code met twice a week before school for 15 weeks; eCYBERMISSION met once a week and five meetings during lunch in the duration of 16 weeks; Science Olympiad met once a week for 13 weeks; and SeaPerch/robotics group met twice a week and five additional lunch meetings for 15 weeks. Of the sampled students, half participated in multiple OST STEM activities. For example, one student who primarily participated in Girls Who Code also participated in Science Olympiad, two students participated in both eCYBERMISSION and Science Olympiad, and most (seven) students who participated in SeaPerch, also participated in another OST STEM activity (mainly Science Olympiad).

Assumptions, Delimitations, and Limitations. The following assumptions were made about the participants within the case that these students chose to attend OST STEM activities and were not compelled to do so. Although attendance data was not taken, observations provided understanding that the 15 case participants were in regular attendance of and engaged fully in the OST STEM activities. It is assumed that the students were truthful and accurate in their interviews and questionnaires of their experiences in the OST STEM activities, respectively. The delimitations that were applied to this case is that is it specific to the experiences of these 15 students within the four OST STEM activities that occurred on their school campus, and although there may have been other positive (or negative) experiences students had in their OST STEM experiences, it was bounded to their interest in and motivation for STEM. And, this being a case study, is limited in both methodology and scope, and does not intend to generalize about students affective experiences in all OST STEM activities, or exact nature of their specific experiences in the individual OST STEM activities named.

Data Collection. Qualitative data were collected over the course of the spring semester 2017. The questionnaire was administered first, at the beginning of students' participation in OST STEM activities. Observations then were made of students during OST STEM activities and interviews were conducted at the end of the OST STEM activities.

Questionnaire. A 12-item questionnaire was used to gather basic demographic information as well as each participants' thoughts about reasons they chose to participate in OST STEM activities. Information collected from this instrument included age, grade, gender, family members in STEM fields, involvement in STEM activities. Five open-ended responses provided insight into the students' STEM interests and motivations. Sample questions included "What sparked your interest in STEM?" and "Why did you decide to come to [OST STEM activity]?" This questionnaire was intended to gain information about the students' background information and OST STEM experiences to explore their motivation and interests prior to OST STEM participation.

Observations. The researcher took field notes during 78 observations of case study students during OST STEM activities using a semi-structured observation instrument. The observation protocol was developed using the research question as a guide and considered both constructs of motivation and interest within the conceptual framework. Sample items for observation were "What are they doing?" and "What is the content and topic of discussion?" These observations provided the researcher the opportunity to view the students during their OST STEM activities such to provide additional insight into their experiences. However, it should be noted since case participants were interacting with non-research participants the data is non-specific, meaning, it allowed the researcher to be able to compare the observed data with other forms of data collected to provide a holistic understanding of sampled students OST STEM experiences and the sources of interest and motivation therein.

Interviews. Fifteen-minute interviews were conducted and audio recorded with each student participant towards the end (i.e., week 14, 15, 16) of their respective OST STEM participation. The 11 interview questions were developed similarly to the observation tool, using the research questions as a guide and informed by the conceptual framework of student motivation and interest in STEM related to participation in OST STEM activities. For example, questions asked "how did you get involved in [OST STEM activity]?" And "How has [the OST STEM activity] affected your decision to continue or not continue with future STEM activities?" During the interviews, the interviewee's responses were restated for clarification and by asking follow-up questions. Interviews were deidentified using pseudonyms and transcribed for coding purposes. Table 1 shows the assigned pseudonyms and demographic information (grade level and gender) of the 15 case study students.

Table 1.

Pseudonyms of Students (N = 15) by Grade Level and Gender (in Alphabetical order)

	6 th Grade (n = 2)		7 th Grade (n = 7)		8 th Grade (n = 6)	
	Male (n = 2)	Female (n = 0)	Male (n = 3)	Female (n = 4)	Male (n = 2)	Female (n = 4)
Pseudonyms	Emmitt		Otis	Amy	Hamilton	Catherine
	Harry		Paul	Jennifer	Simon	Gina
			Kevin	Paige		Helen
				Sarah		Kimmy

Data Analysis. The focus of the analysis was to identify specific trends and recurring (sub)themes, related to motivation and interest, among the 15 students who participated in one or more OST STEM activities. An audit trail was established to chronicle the data analysis using the following convention: identification of the primary OST STEM Activity (eCYB for eCYBERMISSION, ScOI for Science Olympiad, GWC for Girls Who Code, and SeaP for SeaPerch/robotics program); data type (I for interview and Q for questionnaire); reference number (interview source (student) or questionnaire item), and location within the data set (line numbers for interviews and letters for questionnaires). The data analysis of the interviews, questionnaire, and observations led to the establishing of subthemes under the central theme of interest and motivation.

Trustworthiness. Trustworthiness was supported through the collection of multiple types of qualitative data using the 4-tier paradigm espoused by Lincoln and Guba (1985). For credibility, prolonged engagement with subjects (over 3 months) and triangulation of multiple data sources afforded confidence in the findings. Regarding transferability, the nature of this case study is limited in transferability, however, the methods provide a fairly comprehensive snapshot of students experiences in their OST STEM activities. Dependability, or the consistency of findings, was established through multiple measures of data collection and clarifying students' responses during the interview process. Consistent use of protocols was applied to record data and document evidence of students' attitudes and interest during their participation in OST STEM activities. Last, an audit trail aided confirmability.

Results

Data collected from the participants of the study revealed a range of influential factors that were interesting to and motivating for students related to their OST STEM participation. The data analysis of the questionnaire, observations, and interviews led to the emergence of the major theme *Sources of STEM Motivation and Interest with related subthemes of Self-Motivation and Intrinsic Interest* (30% of codes); *STEM Activities and Content* (18% of codes); *Teachers* (19% of codes); *Family* (11% of codes); *Friends* (9% of codes) and *Supporting Others: Outside of School Organizations or People* (2% of codes). Each of these subthemes represented an influential aspect of students' (reported or observed) interest and motivation to continue their learning of STEM.

Self-motivation and intrinsic interest. Among the subthemes, self-motivation and intrinsic interest was most prevalent; comprising of data when students demonstrated (observations) and expressed (interviews, questionnaire) their personal interests for STEM learning and their self-motivation for pursuing their specific (OST) STEM activities. All participants listed themselves as a source of inspiration and encouragement for joining their specific OST STEM activity. In the questionnaire, 60% of students listed themselves as a reason for joining their chosen OST STEM activity. When asked "whose opinion do you value the most and why?" and "Who encouraged you to participate in the activity?" Two female students, Kimmy (8th grade) and Paige (7th grade) wrote that it was, "My own because it looked like a good field to be involved in" (ScOI.Q4.H), and "I value my own opinion over others' opinions because I am the one to eventually make the decision" (eCYB.Q4.H), Otis (7th grade male), reported that his interest in robotics was sourced from within: "I have a lot of trust in me" (SeaP.Q30.H).

Further, students explained how their self-motivation supported their wanting to participate in OST STEM activities. When students were asked about why they joined their OST STEM activity, Helen (8th grade, female) stated, "We thought it would be fun, and we thought it would be good to excel in engineering and grow as engineers" (ScOI.I2.75). Emmitt, (6th grade, male), explained, "I just really like robotics, and umm I just am really into robots, and I really like coding and yeah. It just really interests me, yeah, and I just feel great while I'm doing it" (SeaP.I3.152). Kevin (7th grade, male) stated, "I'm just kind of interested in engineering altogether and experimenting with stuff" (SeaP.I7.433). These students expressed how important these OST STEM activities were to them and how their interests motivated them to become STEM-minded students. Other students mentioned similar intrinsic interests for learning STEM. When asked about having any prior STEM experiences, Kevin discussed, "I kind of build stuff at home" (SeaP.I7.441); this is a reference to his interests in tinkering and building on his own time. He went on to explain that his choice of being part of the robotics groups has pushed this interest further: "I just kind of started the building with stuff, and robotics got me more in-depth with engineering; so

I just kind of learned more and started to explore more" (SeaP.I7.451). Amy (7th grade, female), who participated in Girls Who Code, explained how she was using her activity to explore more and advance her interests when she stated, "I'm particularly interested in fashion design, and so I feel like that comes along with engineering now. And I think it's cool to figure out how things are made and sort of create stuff" (GWC.I8.516). She went on to explain, "I'll probably do some stuff online, keep practicing" (GWC.I8.551). She was referencing her working on online coding tutorials at home, guided by her own independent interest.

When the students were asked about why they chose to participate in their OST STEM activities, they expressed their personal interests in their decision making. Hamilton (8th grade, male) explained his decision to participate in the robotics program when he stated, "Well when I came to middle school, I've always been interested in engineering, and I just wanted to try something new. And so, I showed up for robotics club, and I just had a knack for it. And I really loved it" (SeaP.I13.828). Another student named Harry (6th grade, male) explained that he joined the robotics group due to his enjoyment of programming when he stated, "I enjoy doing it, and I enjoy programming and inventing and doing it my own way" (SeaP.I9.569). Furthermore, when asked what it was about programming and inventing that inspired him, he explained, "I think, it's just the way, I just enjoy it" (SeaP.I9.570). His statement suggested that he focused on his own enjoyment and personal connection to the activity. Harry went on to say that he wants to continue pursuing engineering in the future through college because "It's just a place where I feel happy, and it's something I enjoy doing" (SeaP.I9.601). Gina (8th grade, female) discussed that she joined Science Olympiad to satisfy her competitive nature. Gina stated, "My personal motivation because I really like being able to create things like how I want them to be" (ScOI.I10.669). Simon (8th grade, male) discussed his life-long interest in engineering: "According to my parents, when I was little, I liked to watch this engineering show" (SeaP.I11.710). In the observations, a majority of the students demonstrated interest in pursuing STEM learning during their respective OST STEM activities. Each observed student (15) had one instance of engagement through body language. In the observations, students showed the same motivation for their STEM activities by excitedly coming to their OST STEM activities before and after school, and expressing their desire to do more during lunch and recess time.

Teachers. The second largest subtheme comprised of observed interactions of OST STEM teachers with their students and the comments made by students about their teachers; data related to how they were inspired (to join OST STEM activities) and motivated (in their STEM learning). Teachers were cited by students as encouraging them to participate in the OST activities by speaking to students in class settings, one-on-one, and by promoting OST STEM activities school-wide. Teachers were cited (in the questionnaire data) as supporting students' motivation

for STEM and increasing their engagement, noting that schools' formal engineering teachers and/or the OST STEM teachers encouraged them to join their OST STEM activity. Eight students remarked that the STEM teachers' inspirational attitudes engaged them in STEM learning. During the interviews, students discussed their STEM teachers being inspirational and motivating. Amy discussed how her science teacher who promoted Girls Who Code drove her to join the group (GWC.I8.418). Simon, who participated in robotics activities, explained that "a lot of people related to engineering" (SeaP.I11.734), influenced his pursuit of STEM learning. Furthermore, Kimmy explained how her teacher pulled her aside to recommend her for the Science Olympiad competition. This student went on to state, "It excited me about it, so I entered and then continued on this year" (SciOI.I15.981); other students (Helen, Gina, and Sarah) reported similar, positive experiences with their Science Olympiad teacher. In all, seven (of the eight) female students referenced their female teachers (specifically those who ran the Science Olympiad and eCYBERMISSION activities) as being a motivating influence. Sarah (7th grade, female) stated that she "pushed her and didn't baby her" (SciOI.I14.946) while Kimmy and Gina described how their teacher had recommended them for their OST STEM activity. The female teacher was referenced by all of the girl participants in Science Olympiad and Girls Who Code. The boys similarly referenced being influenced by male teachers, as participants of the robotics groups were primarily boys. For example, the five (of seven) males referenced the robotics teacher who ran the robotics group. During the observations of OST STEM activities, many of the students were noticeably motivated by teacher comments and feedback. The positive working environment created by the teachers leading a trusting relationship between the teacher and the students. As Kevin stated, "I value my teacher's opinion because he wanted me to try something, and I liked it after I tried it" (SeaP.Q7.H). In all, 12 (of 15) students stated their teachers were a direct inspiration for their joining their OST STEM activity.

STEM activities and content. The next subtheme was based on responses from students (interviews and questionnaires) referencing OST STEM activities or STEM-related content being a source of motivation or inspiration for learning. Hamilton, a robotics student, explained, "I would say it's just that it's just really interesting to me and every time I do something I look back at it and is ah, wow, that's really cool" (SeaP.I13.800). Science Olympiad student Sarah explained that she wanted to do more than just her engineering class when she stated, "I wanted to do something extra for engineering and last year solar sprint was the thing that appealed to me the most and they needed people [for Science Olympiad]" (ScOI.I14.611). Sarah went on to explain, "It [Science Olympiad] was part of what they [peer girls] wanted us doing in engineering and I like competing a lot I like comparing my knowledge to others and seeing what I can do" (ScOI.I14.604). Sarah, when

asked why she chose to participate in Science Olympiad, she explained her Rube Goldberg project from her activity,

I like engineering as a whole and I also like just building things and trying new sort of different activities out. I'd always had an interest in Rube Goldberg for example and I thought it would just be a fun experience to try and build one for like myself and see what it took and where it went to (SciOl.I14.861)

Some students spoke of how enjoyment of the subject matter led to them being motivated to learn STEM. Paul (7th grade, male) explained, "I just like it. I just like learning and making robots and other stuff" (SeaP.I2.446). Furthermore, he went on to state, "I think the more I do robotics the more I like it so I will do more STEM activities" (SeaP.I1.450). Fourteen out of the 15 students interviewed discussed how their engineering course or OST STEM activity's content was important to them. In addition, the observations showed students being involved in their activities, self-selecting activities and having autonomy.

Family. The subtheme of family as a source of motivation and inspiration derived from the number of references students made to family members including parents, siblings, and to a lesser extent, grandparents. In interviews and questionnaires, students reported that family members support their OST learning in STEM.

Parents. First, the majority of students stated their parents had been an influential or inspirational factor on their STEM motivation; and parents as a reason (43% of students) why they were pursuing OST STEM activities. About half of sampled students had a parent in a STEM field, which may be having a positive influence on students' motivation to pursue STEM. For example, Catherine (8th grade, female) in eCYBERMISSION, stated, "I remember talking with my parents about STEM. They told me what they do in engineering and computer programming, and that sparked my interest" (eCYB.Q29.L). Furthermore, Sarah expressed a similar thought when she stated, "My dad was an engineer and always taught me how to build things, take things apart, and put things back together" (ScOl.Q19.L). Other types of support was through parental value on and expertise in STEM. Helen explained, "I value my parents' opinion the most because they are people who I can talk about STEM to deeply. They explain to me some about computer programming and engineering" (ScOl.Q15.H). Otis stated, "I value my parents' opinion because of their success in their fields. I have a high appreciation for STEM activities because of them" (SeaP.Q10.H). Other students reported being compelled to participate, like Jennifer (7th grade, female) who stated, "they know what's best for me" (ScOl.Q15.H2) and Emmitt, who claimed "my parents encouraged me to do so" (SeaP.Q34.L). Two students (Simon and Amy) explained that their parents looked explicitly at opportunities for them to participate in OST STEM activities.

During the interview, Otis explained, “My parents introduced me to the idea [OST STEM activities], and I thought it would be fun. When I was in sixth grade and first did it, I stuck with it through middle school” (SeaP.I4.215). Otis’s parent introduced the idea of participating in an OST STEM activity, as well as encouraged him to participate. When asked about who had helped or inspired her to continue learning about STEM, Kimmy explained, “My parents are proud of me for doing it. So, it’s sort of like good, and it influences me” (ScOI.I15.1021).

Siblings. Five students referenced their older siblings as providing motivation and inspiration for pursuing STEM learning. Helen explained that her older brother’s influence was important because he too was participating in STEM learning; her brother is currently majoring in engineering in college. She stated, “I think what inspired me personally is my brother, who is in college right now studying engineering and doing an internship” (ScOI.I2.81). Two other students referenced an older sister’s STEM experiences. Catherine stated, “My sister created many fun projects that I wanted to do, too” (eCYB.Q24.L) and Paige said, “Again, my sister did eCYBERMISSION three years in a row and won regionals twice. I was hoping to follow in her footsteps and was not disappointed” (eCYB.Q18.L). Older siblings were reported as exposing younger siblings to STEM activities and inspiring them to pursue OST STEM interests. Emmitt referenced his older brother as a source of motivation for wanting to pursue STEM learning; “My brother influenced me actually on my old computer” (SeaP.I3.157). Jennifer said, “I know my sister is really into engineering, and she really wants to be an engineer. And I really want to follow in that path a little bit because she does a lot of projects that do some of the similar things” (ScOI.I5.342). Catherine provided a similar sentiment, “I also saw some of the projects my sister was doing, and I thought it would be cool to do them” (eCYB.I6.420). Lastly, Jennifer discussed in her interview that her dad (a computer programmer) had been working with her and her sister (not in the research study) to support their coding skills (ScOI.I5.349).

Grandparents. Grandparents were also cited as inspiring and influencing students’ choices for pursuing OST STEM learning. During the interviews, two students (Amy and Simon) revealed their grandfathers were engineers. Amy explained how her grandfather’s occupation persuaded her mother to encourage Amy to pursue STEM, “Well my grandfather is an engineer, so my mom has always been really big in me taking engineering” (GWC.I8.530). Simon spoke of his grandfather and father both being engineers and how he wanted to follow in their footsteps (SeaP.I11.691). In all, three students referenced their grandfathers as STEM mentors, particularly citing the importance of their grandfathers’ engineering backgrounds.

Friends. The subtheme of friends derives from students’ references to their friends being an influential factor in their participation, interest and motivation for their OST STEM activity. During the interviews, students made comments about their connections to their friends and

referenced them as a source of their motivation for joining their OST activity through camaraderie and companionship. Six of the 15 students interviewed stated that their friends were influential in their decision to participate in an OST STEM activity. Paul explained, "I encouraged some other friends who had done summer camps and other things along those lines" (SeaP.I1.31) where Helen said, "We thought it would be fun. We thought it would be good to excel in engineering and grow as engineers" (ScOI.I7.76). Both statements speak to the importance of friends and wanting to do the (OST STEM) activities together. Students also referenced their collaboration with their peers as a source of inspiration for participation in OST STEM activities. Otis, when asked a follow-up question regarding why he kept doing robotics since sixth grade, he stated,

I like the team aspect, especially with [Robotics] three or four-person teams. It was fun to work with my friends, and I think if it was a project with you by yourself, it wouldn't be as fun or as satisfying.... We decided this seemed fun, so we started doing it, and then we liked it. So we continued" (SeaP.I4.219)

Friendship provided inspiration and influenced the joining of activities, which was seen when Kevin stated, "A lot of my friends are doing it, and they thought it was cool. So, I thought I could do it too. And if I liked it, I could continue" (SeaP.I7.465). Furthermore, students were finding enjoyment in completing STEM projects associated with an individual activity, such as Science Olympiad's mousetrap car challenge, with peers and friends. Paul explained that his friends and his enjoyment for STEM led him to join his robotics group "because my friends do it, and I like STEM" (SeaP.I1.68). Harry explained that his friends influenced him to join his STEM activity when he stated, "my friend was doing it...[when] me [sic] and my friend were talking about it, and then I decided" (SeaP.Q32.K). Further, Harry explained that because he valued his friends' opinion and encouragement, he decided to pursue his STEM activity. Whereas Otis stated, "my friend said it was fun" (SeaP.Q30.K), which facilitated his participation. The majority of the comments that pertained to the role friends' encouragement and influence to join an OST STEM activity came from male students.

Supporting others: outside of school organization or people. The subtheme of supporting others was derived from the students' references to non-school/activity related persons, groups, topics, and organizations which had inspired motivation for STEM learning. Only a small group of students mentioned this as a source of inspiration. Paige, who was involved in eCYBERMISSION, to a question about which of the STEM activities was the most important: "The Verizon App Challenge, because I got to learn about and try to help people with Down syndrome" (eCYB.Q23.J). Catherine, who had been working with classmates from a former class on a grant supported by Massachusetts Institute of Technology, stated, "I really enjoy our project for the Massachusetts Institute of Technology grant because it has the potential to help people"

(eCYB.Q3.J). Paige and Catherine reported motivation and interest (in STEM) through humanitarian opportunities. This was also mentioned by Sarah (also in reference to eCYBERMISSION), “I wanted to be able to make something that would help other people” (eCYB.Q21.K). Helen, a Science Olympiad student who was asked to think back on what event, class, or conversation sparked her interest in STEM learning, explained her work in supporting others in her engineering class this way,

I was hesitant to take the class and completely ready to drop it for a study hall. But when we were given the opportunity to work in small groups to brainstorm, design and build a prototype, and figure out how to implement an idea/invention that would help our community, I realized how interested I was in the class. I was excited for that period, and making a breakthrough felt so gratifying. I do believe though, that the experience would not have been as fulfilling if we were not granted the freedom that we had been.
(ScOI.Q15.L)

Notably, there were no references made by any of the male students about being interested or motivated to pursue OST STEM activities stemming from desire to help or support other people. Moreover, there were references in the questionnaire responses and interview data of specific persons who had inspired some students to engage in STEM learning. For example, Simon identified his Boy Scout troop leader as a STEM mentor (SeaP.I11.734). Sarah referenced one of the female character leads in the movie *Hidden Figures* (2016), in response to a question about who has inspired you, when she explained, “The women in *Hidden Figures*. She is 93 right now. She was a big inspiration because everyone was telling her she couldn’t do it” (ScOI.I14.954). Sarah went on to describe how that woman from *Hidden Figures* overcame obstacles, which was a root source for her inspiration to learn STEM.

Lastly, students referenced outside organizations (of school or OST STEM activities) that were inspiring them to pursue STEM. For example, engineering and science merit badges from the Boy Scouts of America (SeaP.I11.703) and the *Hour of Code* (2019) each served for certain students as a catalyst for wanting to learn more STEM content (GWC.Q31.L). When asked to explain when and how Harry had first been inspired to take part in OST STEM activities, he answered, “in third grade, when I did afterschool with Young Engineers” (SeaP.Q33.L). The desire to help others and individuals outside of the school setting that are connected to STEM student learning each motivate some students to participate in STEM activities.

Discussion

This case study sought to illustrate, and to a much lesser extent evaluate, what were the sources of 6th to 8th grade students’ interest in and motivation for STEM learning, derived from

their sustained participation (over several weeks) in at least one of four established OST STEM activities. Students reported high levels of personal interest and intrinsic motivation, important constructs for students' STEM learning and future STEM persistence (DeJamette, 2012; Nugent et al., 2010). Fourteen out of fifteen students during their interviews discussed how important their OST STEM activities were to their personal interests, spurring their prior participation in or current participation in multiple OST STEM activities (Young, Ortiz, & Young, 2017). Next, students referenced how they enjoyed the collaborative and goal-driven OST activity and content; which also has been shown to support students' interest in and motivation for STEM learning (Hayden et al., 2011; Mohr-Schroeder et al., 2014; Nugent et al., 2010). Furthermore, enjoyment of the (inter)active hands-on learning that was reported and observed by the students in this study affirms positive effects found in previous work on students' STEM learning (Freeman et al., 2014; NRC, 2010; 2013), and now, interest and motivation demonstrated by the self-selection of the OST STEM activities and participation therein on specific OST STEM projects. The sustained duration of the OST STEM activities is likely to have played a significant role in fostering students' interest and motivation; Allen et al. (2019) found significant non-cognitive improvements among adolescents who participated in four or more weeks of OST STEM activities. Regarding people that were influential to students' interest in and motivation for learning STEM, in relation to the OST STEM activities, nearly half of the students in this study had at least one parent in a STEM field supporting the development of these students' interests in and motivations for STEM learning. This finding of parents influencing motivation to pursue STEM learning is similar to that of prior research on the influence of family on STEM learning outside of school (Archer et al., 2012; Archer et al., 2010; Aschbacher, Ing, & Tsai, 2014; Corin, Jones, Andre, & Childers, 2018; Maltese, Melki, & Wiebke, 2014). Although family members (parents, siblings, and grandparents) are external to the students' real-time OST STEM experiences, they still played a major role in the students' initial and continued STEM interests and motivations, which may influence the nature of their OST STEM activity participation. Teachers were identified as a major source of positive affect, in particular for the girls in this study; the female OST STEM teacher was cited as a reason for girls' initial and continued participation, confirming prior research findings on the affordances of same-background (Mosatche, Matloff-Nieves, Kekelis, & Lawner, 2013), same-sex formal (Ahmed, 2016; Weber, 2011) and informal STEM activities (Chun & Harris, 2011; Hite, Midobuche, Benavides, & Dwyer, 2018; Hughes et al., 2013). This provides greater understanding to the known role of teachers in influencing students' learning, interest in and motivation for STEM (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012; Holmquist, 2014; Jensen & Sjaastad, 2013; Makhmasi et al., 2012), specifically in OST STEM spaces. Friends were also cited as important to student interest and motivation, which confirms previous findings that positive peer relationships in a STEM learning environment help foster a sense of community to enhance student learning of STEM (Chun &

Harris, 2011; Smith, Douglas, & Cox, 2009) and support students' interests in STEM (Abernathy & Vineyard, 2001; Brown, 2016; Modi et al., 2012; Mohr-Schroeder et al., 2014; PCAST, 2010; Weber, 2011; 2012). Last, other persons were found to only play a modest role, perhaps due to how removed they are from the students' daily lives. However, research has found that the Boy Scouts of America's provides students with influential role models for crafting positive and supporting OST learning environments (Hershberg et al., 2015), suggesting cumulative OST STEM experiences may play a role in enhancing interest in and motivation for STEM.

Conclusion

In sum, the four OST STEM activities examined in this study provided participating middle grades students with opportunities to pursue their STEM learning with encouragement from teachers, family, as well as their friends, which furthered their STEM interests and motivations. Notably, the greatest affective affordances for students' interest and motivation were sourced from the environments of OST STEM; from which students described how they engaged in active, hands-on collaborative, goal-driven activities, largely driven by their own volition. The findings suggest a few avenues for further action and research. First, revision of OST STEM curricula to more actively foster student interest and motivation through enhancing elements that students reported, in this study, to be the most important to sustain their ongoing participation. Next, this provides some insight in ways to bridge family and peers into OST STEM activities, strengthening the extant relationships between students' personal and social lives to potential OST STEM opportunities. Last, educating teachers on the availability and importance of OST STEM activities such to empower them to actively and directly encourage their students to participate. By intentionally nurturing middle grades students interests in and motivation for STEM, coupled with strategies to effectively measure affect within OST STEM programs (Grack Nelson, 2017; Shah, Wylie, Gitomer, & Noam, 2018), may we hope to retain adolescent students' interest in and motivation for STEM in high school and beyond.

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