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Journal of Science Education and Technology

ISSN 1059-0145

J Sci Educ Technol
DOI 10.1007/s10956-014-9490-z

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Interest-Driven Learning Among Middle School Youth in an Out-of-School STEM Studio

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Abstract The concept of connected learning proposes that youth leverage individual interest and social media to drive learning with an academic focus. To illustrate, we present in-depth case studies of Ryan and Sam, two middle-school-age youth, to document an out-of-school intervention intended to direct toward intentional learning in STEM that taps interest and motivation. The investigation focused on how Ryan and Sam interacted with the designed elements of Studio STEM and whether they became more engaged to gain deeper learning about science concepts related to energy sustainability. The investigation focused on the roles of the engineering design process, peer interaction, and social media to influence youth interest and motivation. Research questions were based on principles of connected learning (e.g., self-expression, lower barriers to expertise, socio-technical supports) with data analyzed within a framework suggested by discursive psychology. Analyzing videotaped excerpts of interactions in the studio, field notes, interview responses, and artifacts created during the program resulted in the following findings: problem solving, new media, and peer interaction as designed features of Studio STEM elicited evidence of stimulating interest in STEM for deeper learning. Further research could investigate individual interest-driven niches that are formed inside the larger educational setting, identifying areas of informal learning practice that could be adopted in formal settings. Moreover, aspects of youth's STEM literacy that could promote environmental sustainability through ideation, invention, and creativity should be pursued.

Keywords Connected learning · Informal STEM education · Middle school youth · Interest-driven learning · Engineering design-based science learning

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Introduction

A recent survey of online participation and political engagement found that youth engaged in interest-driven activities are significantly more likely to invest in civic and political activities (Cohen and Kahne 2012). This bodes well for out-of-school STEM (Science, Technology, Engineering, and Mathematics) programs that include a civic or political feature such as community involvement or environmental activism. Moreover, connected learning environments are centered on networks of interest and expertise that have high standards for good work and credible information (Ito et al. 2013). Despite these encouraging findings, need exists for increased performance of middle school youth as indicated by international assessments of academic success to spur larger pools of domestically trained professionals in STEM and information and communication technologies (ICTs) (United States National Science Foundation 2004).

Published online: 26 March 2014

In the context of these trends, STEM education researchers and learning scientists suggest that interest and motivation could be significant prerequisites to effecting these situations (Asghar et al. 2012). Inspired by emerging evidence, Studio STEM was developed as an out-of-school program (afterschool and summer program versions) to engage middle school youth in STEM through engineering design-based science learning (Schnittka and Bell 2011). The middle school years are an influential time—providing opportunities that tap interests could be powerful to motivate youth to engage with and persist in STEM (Pellegrino 2012).

The National Academies Committee on Defining Deeper Learning and 21st Century Skills concludes that while there is growing interest in what they call *deeper learning* that can transfer between disciplines and contexts, systematic research on these forms of learning and related dispositions is sparse (Pellegrino 2012). Studio STEM aimed to implement an engineering design-based science learning approach that adopts successful aspects of problem-based learning while pinpointing *deeper learning* that would transfer from numerous contexts and disciplines (Schnittka et al. 2012). The potential innovation of Studio STEM, which distinguishes from comparative programs, is to tap into youths' investments in social media, virtual worlds, and video games (Merchant 2012). As Subramaniam (2012) has pointed out: "Many technological interventions have surfaced, such as virtual worlds, games, and digital labs, that aspire to link young people's interest in media technology and social networks to learning about STEM areas" (p.161).

The construct *connected learning* has recently guided research and design associated with Studio STEM. Connected learning seeks to expand the range of cultural institutions perceived as entry points and pathways to educational and workforce opportunities. According to Ito et al. (2013), there are many aspects of connected learning that have consequences for the design and research of out-of-school learning settings:

> "Connected learning looks to digital media and communications to: 1) offer engaging formats for interactivity and self-expression, 2) lower barriers to access for knowledge and information, 3) provide social supports for learning through social media and online affinity groups, and 4) link a broader and more diverse range of culture, knowledge, and expertise to educational opportunity" (p. 6).

In the following sections, we detail how Studio STEM has appropriated principles from connected learning to design an intentionally engaging and motivating out-of-school STEM learning experience as well as guide the formulation of research questions to construct rich descriptions of youth interest and motivation via in-depth case studies. The investigation highlights key cognitive, social, and technological competencies that deserve further attention for informal STEM research and practice. Table 1 provides a comprehensive summary of the literature review in terms of the intentional design features of Studio STEM.

Problem-Based Learning and Informal STEM Learning

Merging interests, peer culture, and academics are key to the success of informal learning settings, where *problem-based learning* (PBL) informs participants of current global issues to utilize design processes to solve those problems (Ito et al. 2013). In informal environments, youth benefit from participating in programs that provide opportunities to ask questions without penalty, explore new concepts, and think through realistic problems that society faces. When youths' interests increase, their excitement increases. When youth are more connected with their passions, they are more willing to learn about and correct society's problems, thus potentially affecting global sustainability (Asghar et al. 2012). PBL is an instructional strategy that fits well with the goals of integrative STEM education as it parallels in many ways engineering design processes. Also, PBL allows youth to apply content knowledge to real-world problems to propose a solution (Siegel et al. 2000). PBL features simulate many aspects of practicing engineers who apply concept knowledge and logic skills to a current problem through the process of designing, testing, and redesigning (Brophy et al. 2008). PBL involves experiential learning through the investigation, explanation, and resolution of meaningful problems (Barrows 1998; Torp and Sage 2002).

The integration of PBL curriculum allows youth to delve into their interests and utilize design processes to solve meaningful problems such as global sustainability issues. A model of this type of learning is described as *islands of expertise* by Crowley and Jacobs (2002). The role of *islands of expertise* serves as a catalyst for youth interest by building up each individual's *island* with support from various media (Ito et al. 2013). Crowley and Jacobs (2002) define an island of expertise as "a topic in which children happen to become interested and in which they develop relatively deep and rich knowledge" (p. 2). Instead of dismissing pop culture, technology, and media, *islands of expertise* embrace each as a tool to help individuals explore varying academic interests.

Honey and Kanter's *Design, Make, Play* (2013) provides support for adopting PBL as related to informal STEM learning. The authors' propose a methodology that includes the following: the design of multiple solutions based on specifications, the building and testing of models, and the

Table 1 Summary of the literature review as it relates to design features of Studio STEM.

Design features	Definition	Empirical examples	Studio STEM
Problem-based learning	Problem-based learning (PBL) is the integration of the engineering design process into theories of learning and topics in STEM subjects	The PBL process includes the designing process, the making process, and the playing process (Honey and Kanter 2013) PBL involves experiential learning through the investigation, explanation, and resolution of meaningful problems (Barrows 1998; Torp and Sage 2002) In PBL, problems should be used as a "trigger" for learning while youth collaborate in small groups (Schmidt et al. 2011)	*Engineering teaching kits:* introduction to a global problem, Save the Seagulls Badge stations set up for research Design stations Building stations Analysis of the participant's work as compared to other participants through a symposium
Social media and digital tools	Social media and digital tools are the new media that is available for use in informal and formal learning environments including social network forums, information communication technologies	Tools like social network forums (SNF's) can be personalized to support a diverse set of learning styles and paces to meet very unique needs. These technologies foster engagement and self-expression to boost interest-based learning (Ito et al. 2013) Opportunities that provide hands-on experiences with scientific instruments or technology lead to a higher interest in material (Swarat et al. 2012) Through the exploration of SNFs, students are able to utilize personal interests and learn how those interests apply to real-world issues (Grimes and Fields 2012)	Access to a personal iPad Access to an educational SNF, i.e., Edmodo Participants document their design process and experience through the Notebook + app Participants can reference content-filled PREZIs

improvement of current solutions. The *making* process allows youth to determine how to build using everyday objects such as Legos beyond their normal uses. It shows youth how a normal object could be used for many purposes; ultimately, *making* teaches one to think laterally. Nevertheless, the emphasis is on the voluntary *play* process that has no extrinsic goal except for the participants to learn to enjoy the PBL model (Honey and Kanter 2013). The unique opportunity presented to youth for learning and success in an informal setting meets the needs critical to adolescent development that cannot always be met in more formal settings. Studio STEM has incorporated as much choice into the program to reinforce the benefits of voluntary learning through tinkering and play.

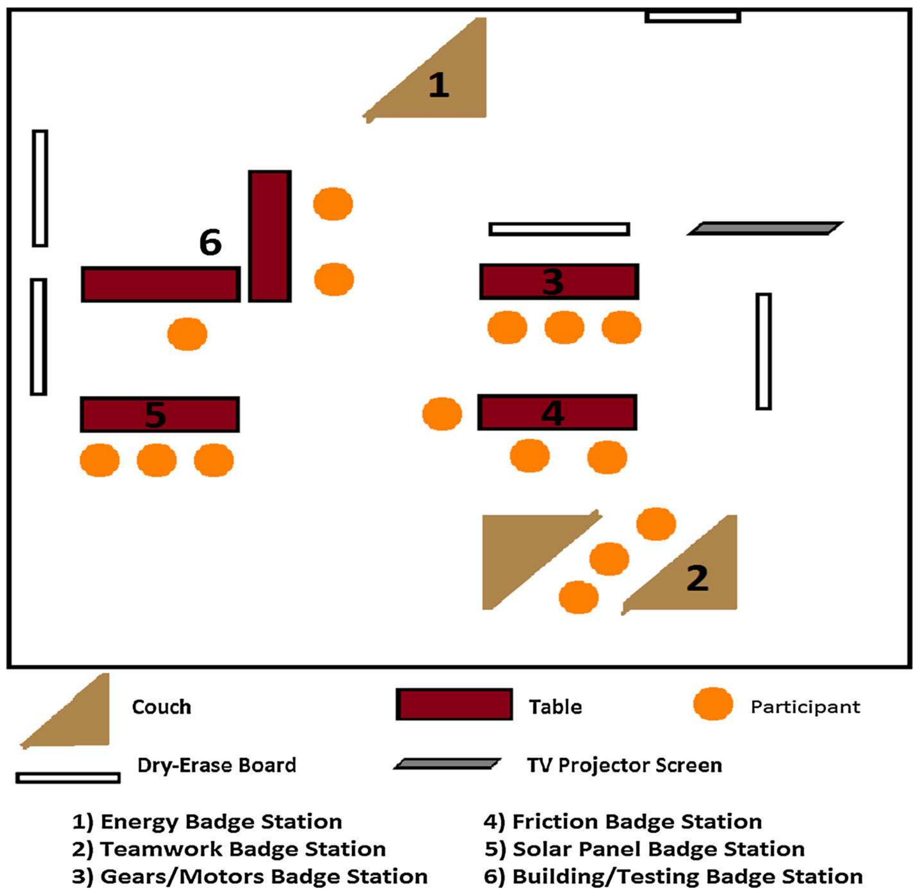
PBL is intertwined with Studio STEM via *engineering teaching kits (ETK)* (Evans et al. 2014; Schnittka and Bell 2011). Take as an example the *Save the Seabirds* ETK, which challenges youth to consider the potential harm caused to the environment by human overreliance on nonrenewable energy sources. The primary challenge posed by the ETK is to construct a solar-powered vehicle to pull the most mass (in the form of pastel and plastic *seabird* eggs at varying weights) through a series of challenges tied to science principles. Participating youth are introduced to scientific concepts of *work*, *force*, and *energy* as they tinker with motors and gears, current and voltage, and the friction of tires made of varying materials to build iteratively a vehicle in competition with other teams. The *islands of expertise* model is also incorporated into the current program by having these various stations for each child to explore and build a broader understanding of various STEM-related subjects. Stations are established in a studio setting for free-choice exploration of gears, motors, solar panels, and Legos (see Fig. 1). Additional information regarding the Studio STEM learning environment is provided in the Methodology section.

After designing a prototype, participants can test their designs at a specific station, recording results on a tablet compute and planning for the next iteration. At the end of the program, participants are given a chance to present their team's ideas and prototypes through a symposium. Additional information about the symposium can be found in the Additional Data Sources section.

New Media and Informal STEM Learning

A determining factor in how well informal learning is adopted into intentional learning environments is the

Fig. 1 This figure is a diagram of the studio space used for Studio STEM



integration of new media into the curriculum (Ito et al. 2013). New media includes the following: social networking forums, interactive media and productivity tools, and mobile computing. An advantage that pushes for this adaptation is the availability of new media that does not need to be invented for the program to work because they have already been created. These tools like social networking forums (SNF's) can be personalized to support a diverse set of learning preferences and pace to meet individual needs. New media fosters engagement and self-expression to boost the interest-based learning that is so highly recommended (Evans et al. 2014). Instead of marginalizing popular culture, and technologies and media often used for recreational means, informal learning embraces each as an expressive tool to explore varying academic interests (Ito et al. 2013). In an era of technologized sociability, the human experience with mediated communication is significant in itself as social interaction becomes almost synonymous with, and in some cases indistinguishable from, the technology that enables it (Merchant 2012).

Swarat et al. (2012) explain how opportunities that provide hands-on experiences with scientific instruments or technology lead to a higher interest in material. This idea supports the concept of technology in learning because it entails using new media, interest, and material to enhance learning. An example of an SNF as a learning tool comes from Grimes and Field's *Kids Online Report* (2012) through their case study of the Whyville science education virtual world. This particular SNF allows middle-school-age youth to collaborate with others on any aspect of the SNF, explore their interests within science fields, and learn how finances work. Through the exploration of SNFs, youth are able to utilize personal interests and learn how those interests apply to real-world issues. Another example of media playing a role in middle-school-aged youth learning about science is the Web-Inquiry Science Environment (WISE) (Hannafin et al. 2014). WISE provides a place for youth to explore a virtual laboratory through investigation, predictions, and experimenting (Hannafin et al. 2014). Also, WISE uses the feature of scaffolding allowing youth to build on prior knowledge (Hannafin et al. 2014).

Studio STEM utilizes new media by having various stations for participants to explore and build a broader understanding of various STEM-related subjects. The program utilizes social media and technology by providing each participant access to Edmodo, a youth-appropriate social networking forum, and an iPad, tablet computer. The iPad, installed with an Edmodo app along with a

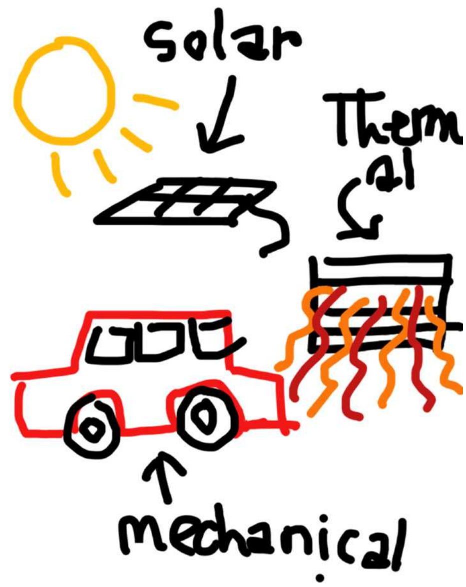


Fig. 2 This figure is an illustration from Ryan's Notebook + app

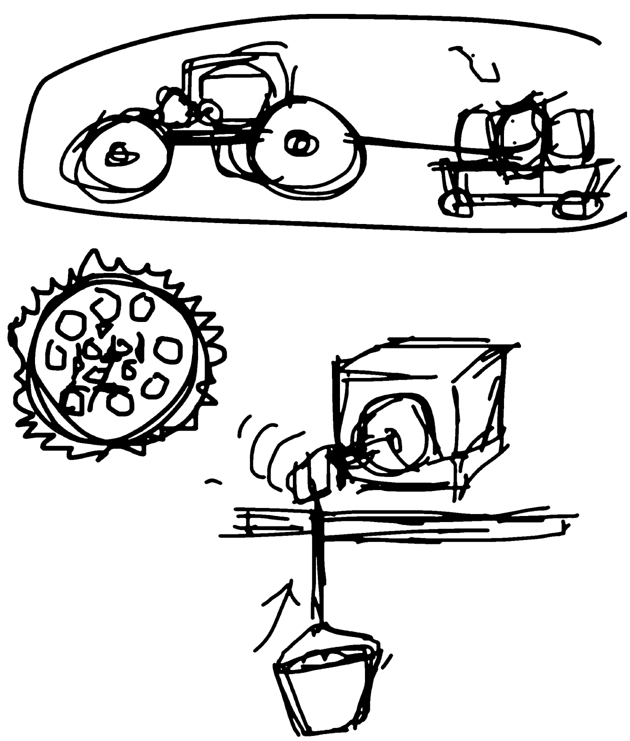


Fig. 3 This figure is an illustration from Ryan's Notebook + app

multimedia journaling app called Notebook +, allows participants to conduct research on science topics more in depth to increase levels of understanding. See Figs. 2, 3, and 4 for examples of Notebook + pages. Edmodo is accessed from the iPad to provide a safe, age-appropriate SNF for participants to discuss ideas, answer content-related questions, and share designing and building experiences. By giving equal weight to problem-based learning,

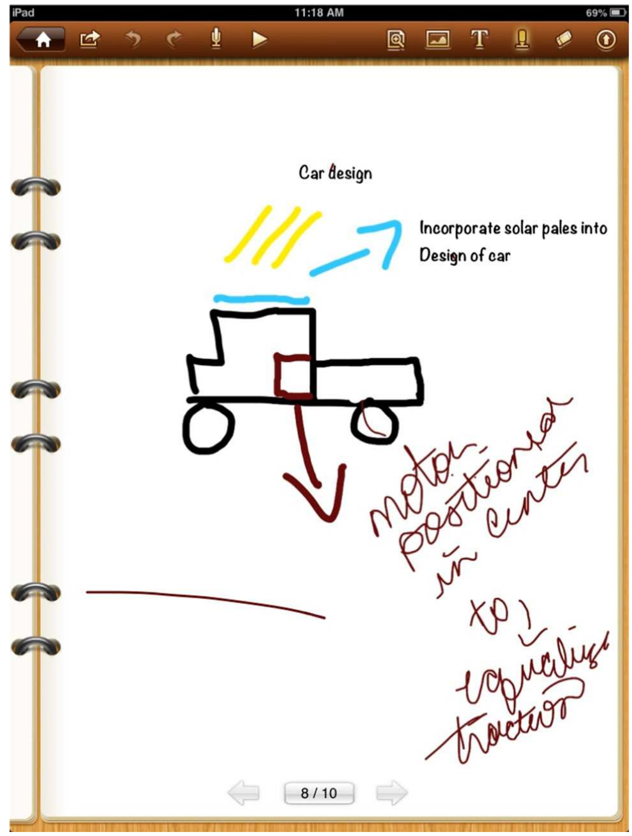


Fig. 4 This figure is an illustration from Sam's Notebook + app

the interaction, and opportunity to socialize through various outlets, and integrating technology in a mindful and purposeful way, Studio STEM looks to create several entry points for youth and offers various ways to engage with the content.

Research Questions

The purpose of this study was to investigate how intentionally designed features of Studio STEM influenced youths' interest and motivation in a studio-based, informal STEM learning environment. Through the Studio STEM program, middle school participants were challenged to solve an environmentally relevant problem using the engineering design process, peer and facilitator interaction, and new media. The program was designed to promote connected learning for participants to tap into inherent interests that could be encouraged for academically focused activities. The study sought to answer the following research questions:

1. What role does the engineering design process play in the motivation of youth that could affect deeper learning? (Honey and Kanter 2013)

2. What role does technology and SNFs play in the motivations of youth to affect deeper learning? (Ito et al. 2013)

Methods

Participants

Studio STEM participants were middle school youth from rural southwest Virginia recruited through a university educational outreach mailing list and by word-of-mouth. Fifteen youth, 6 girls and 9 boys, were enrolled in the one-week program; nevertheless, one girl did not return after the second day of the program. The participants' ages ranged from 10–13-year old. Participants came from three distinct educational backgrounds: home school, and private and public education. Four high school students served as facilitators for the program by being responsible for the curriculum and engaging participants with semi-structured prompts. Four middle school teachers participated in the program as additional facilitators, assisting researchers to note points of interest throughout the week. University faculty members from instructional design and the learning sciences served as project managers, overseeing management of the program and research activities. Two undergraduate research assistants—one from psychology and one from chemical engineering—collected video, field note, and semi-structured interview data.

Learning Environment

The Studio STEM summer program took place in a design studio used by science, engineering, art, and design faculty at a large research university in the Mid-Atlantic. The studio environment boasted a large, open floor plan with tables, chairs, whiteboards, other furniture, and a large HD television monitor that were all mobile. The room was set up as a free-choice environment with workstations for each aspect of the *Save the Seabirds* ETK (Fig. 1). The studio setting is a major component of how Studio STEM instantiates informal learning that prioritizes PBL, peer interaction, and new media. The goal was to place participants in a setting designed for ideation, creativity, and iteration. Program participants were divided into five groups of three participants. Small groups of participants were encouraged because participants build relationships and are motivated to hold each other accountable through peer interaction (Schmidt et al. 2011).

Data Collection Plan

During the Studio STEM program, data were categorized as follows: field notes, video transcriptions, Notebook

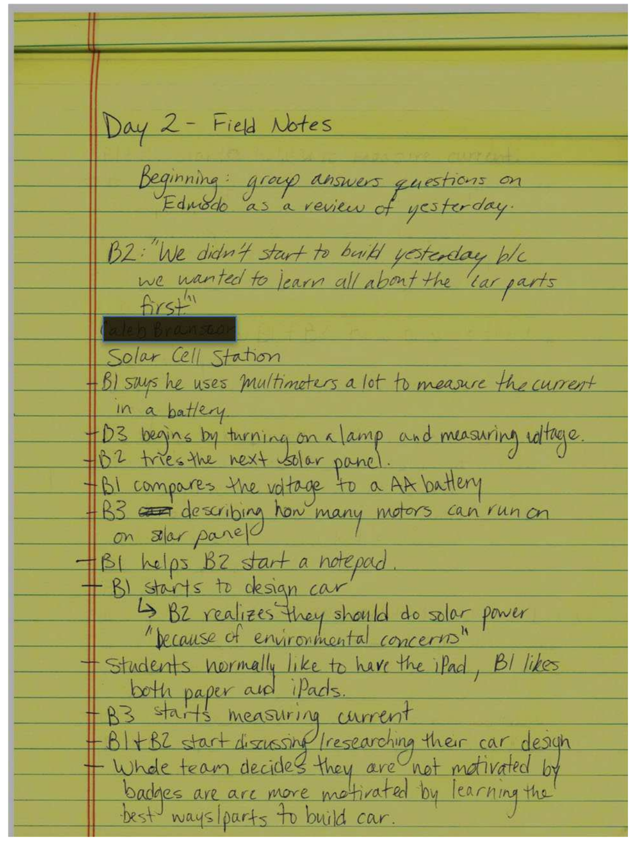


Fig. 5 This figure is an example of a page of research observation notes

+ artifacts, and Edmodo chat log data. The undergraduate researchers carried notebooks to record handwritten field notes on the behaviors and affinities of the participants and facilitators, as well as the tone of the program on a given day. Field notes were used to capture in situ the speech and actions of the participants at the Studio STEM program (Kolodner 2004; Marcu et al. 2013). A sample of field notes from a researcher's notebook can be found in Fig. 5. Edmodo chat was analyzed using the video transcriptions and field notes to determine the situations and the ways Edmodo was used by the participants. That data coupled with the types of talk being posted on the SNF gives researchers a clear picture of the importance and usage of new media in informal learning environments (Walther et al. 2005).

Video is an important method of data collection because it potentially demonstrates the interactional detail that can be observed and stored for comprehensive analysis and reanalysis (Andersen and Nielsen 2013). Video capture allowed researchers to record not only the talk of the participants, facilitators, and other adults, but also the tone of voice, facial expressions, and gesticulations in regard to materials and peers (Barron 2000). The video capturing process allowed researchers the opportunity to make

Table 2 The codebook for video transcriptions of the participants during the program

Categories	Code	Explanation
A. Collaborative learning		
Indicators of motivation	Student generating ideas	Students introduce their own ideas about content/subject matter into discussion in meetings or in group work. The subject ideas do not have to be canonically correct. Is not used when students directly refer to formulation in canonical material
	Content-related questions	Students ask questions related to the subject matter
	Student's uptake of peer's ideas	Students incorporate words or directly refer to utterances from other students
	Gesticulating	Students point or gesticulate in other dramatic ways
	Seeking help	Students actively call the facilitator for help. Is not used when the facilitator helps without being asked
Indicators of demotivation	Overruling peers	Students directly tell peers to shut up, or imply that what they say is not relevant directly or indirectly by not listening
	Easy solutions (shortcuts)	Students' talk or actions directly indicate that students take a short cut to complete the task quickly
	Helpless (giving up)	Students say that they cannot do this task, do not know how to do it, etc. Can also be used when students do not finish the task without saying anything, but with a helpless attitude
B. Alternative assessment		
Badges	Effective incentives	Students actively work toward badges, mention them throughout the program, tried to get team members on board to work toward badges and completed many badges
	Ineffective incentives	Students did not actively work toward badges, did not mention them much, specifically said they did not want to work on badges, did not try to get team members to work on badges
Symposium	Effective form of presentation	Students spent time preparing for the symposium, mentioned the symposium to their team members, and presented excitedly
	Ineffective form of presentation	Students did not spend time preparing for the symposium, did not mention it to their team mebers, seemed confused about the symposium, and/or explicitly stated they did not know what it was
C. Problem-based learning		
Indicators that PBL is supporting motivation/interest	Interest-driven learning	Student seizes opportunity to self-direct learning, noting how situation or problem at hand relates to their interests and experiences
	Iterative process	Student invokes iterative process during the program
	Design thinking	Student engages in inquiry to propose several solutions to problem, identifying what they need to learn, conducting research, reevaluating hypotheses, and reflecting on the design
	Clearly defined problem	Problem is clearly defined at the beginning, and student understands the problem throughout the program
Indicators that PBL is inhibiting motivation/interest	Lack of interest—driven learning	Student refers more to the explicit requirements and constraints of the problem posed without referring to interests or experiences
	Iterative process	Student invokes linear approach, attempting to make first solution work at all costs
	Design thinking	Student neglects to engage in inquiry, choosing to address problem with first and only solution, do not identify knowledge gaps, self-direct learning by conduction research share potential solutions, reevaluate hypotheses, and reflecting on the design
	Problem not clearly defined	Student is not clear on what the problem is, has to ask others what the goal is
D. Technology use		
Indicators that technology supported motivation/interest	iPads	Youth express excitement for using iPads, use them with ease, are using them often, and look like they are enjoying use of the iPads (smiling, laughing)
	Edmodo	Youth post frequently on Edmodo

Table 2 continued

Categories	Code	Explanation
Indicators that technology inhibited motivation/interest	iPads	Youth do not use iPads often, have confusion or difficulty using them, and appear frustrated
	Edmodo	Youth used Edmodo infrequently
Indicators that technology was a distraction	iPads	Youth are enjoy iPads and use them frequently, but are not using it for the purposes of the program

observations in their field notes and listen to the group while videoing the participants (Patton 2002). Video was not recorded during the entire program. The researchers reviewed the curriculum before starting data collection and identified specific points in which the participants would more likely be involved in more highly interactive activities. Those points in the curriculum are where participants were working in their group with the building, design, or presentation materials where there would be the most peer interaction and hands-on involvement with the [Save the Animals] project.

Video was analyzed and coded in two ways for inter-relater reliability to reduce bias. The speech and actions were transcribed to view trends that were present throughout the entire program (Eccles 2005). Observations were an important portion of case study construction as it was not unusual for a participant to say they are doing one thing when in fact doing something else (Corbin and Strauss 2008). Observations helped the researchers to be aware consciously of what the participants were doing during class but not able to articulate during interviews. Triangulation of data collection was important to help address the problem of construct validity. Multiple sources of data provided multiple measures of the phenomenon (Yin 2009).

Two undergraduate researchers used handheld video cameras especially to record the talk and interactions of two participants as a part of different small groups. Each undergraduate researcher focused on collecting data for that one group. On the first day, two case study participants were chosen by researchers to be examined and observed. The participants, one boy and one girl, stood out during the first day while playing the ice breaker game to learn everybody's name. Each participant received a gender-neutral pseudonym, "Ryan" (a female) and "Sam" (a male), chosen based on specific criteria: different genders, opposite ends of the age bracket, and different personalities.

Additional Data Sources

As stated previously, observations from field notes and video recordings were primary sources of data. They encompassed not only the entire group, but also more specifically data for the case studies. The symposium at the end of the program was recorded for researchers to fully understand the content knowledge each participant has at the end of the program. A symposium created an additional alternative assessment based on peer interaction where group members presented their processes, models, and design artifacts to peers and facilitators. The symposium was recorded for transcription and coding as well. For the two case studies, interviews were conducted at the beginning and the end of the program to gauge progress and interests. Those interviews were used to give the researchers' perspective and context into the participants' intrinsic motivations.

The other research artifacts included the following: formal assessments, alternative assessments, and multimedia journals kept by the participants. A formal assessment was given at the beginning of the program, and then, the same assessment was given on the last day of the program through Edmodo to provide a quantitative account of deeper learning. Alternative assessments were provided through a badge system. At each badge station, there was a list of requirements that the participants should complete in order to "earn a badge" that would be checked off by a facilitator. At the end of the week, researchers knew how many badges each team completed. This is a descriptor of how effective the participants thought the badges were. Participants used an iPad application called Notebook + to document their team's progress and design for Save the Seabirds. Researchers analyzed a participant's journal to learn about processing of scientific concepts through the engineering design process.

Data Analysis

The video data collected from group interactions were transcribed, then coded, and analyzed for sequences of talk, action, and nonverbal gesture demonstrating interest and motivation. The codebook also included sections for classification of the engineering design process (problem-based learning), effective assessments, supporting technology, and facilitation interaction. Atlas ti© was used for thematic coding and analysis. Using constructs from the studies presented in the literature review, a codebook was created determining what constituted motivation and demotivation primarily. After the video had been transcribed, researchers examined the data line by line to code the transcription for all of the subcodes mentioned above. Two researchers coded the data for the purpose of inter-relater reliability (Charmaz 2006). By comparing data to data, focused codes were created to help the researcher begin grouping like codes and refining them into larger groups of categories. Coding occurred throughout the data collection process. The finalized codebook can be reviewed in Table 2.

The initial framework for the codebook was based on prior effort that linked interest, motivation, and video analysis (Andersen and Nielsen 2013). The codebook was modified to reflect the focus of the research questions to address interest and learning. Sections such as "Engagement and Interest" were renamed "Collaborative Learning" to better describe the actions and speech of participants encompassing motivation and demotivation (Table 2A). The first code in the motivation section of the original codebook was removed as it described the participants' talk and questioning with teachers. For the purposes of Studio STEM, formal learning interaction was not applicable so that code was removed.

Informal learning as conceptualized and intentionally facilitated by Studio STEM relies heavily on collaboration and group work. Therefore, a section was added to the codebook that took into account a group's or participant's utilization of the engineering design process. The section was named "Problem-Based Learning" (PBL) because the participants collaborated to solve a problem using the engineering design process (Kwan 2009). This section allowed researchers to code whether a participant or group was supporting PBL by allowing their interests to drive their decision-making or clearly understanding the problem (Table 2C). The code leaves room for PBL inhibition when the participants are uninterested in decision-making or do not clearly understand the problem at hand.

The other two codes added to the codebook were technology support, distraction, or inhibition, and effectiveness of the alternative assessments. The technology support, distraction, or inhibition code were added to classify the participants' technology usage throughout the program (Table 2D). The subcodes allowed researchers to see whether the technology was supportive of learning and motivation, distracting from the tasks at hand, or inhibiting the participants from completing the overarching goals of the program. The effectiveness of the alternative assessments subcode was added to encompass the informal learning environment provided by the program (Table 2B). The two alternative assessments were badge and symposium completion. The participants were the drivers of the alternative assessments' effectiveness. If the participants portrayed special interest in the badge stations and described being motivated to complete them, they were coded as effective. Nevertheless, if the participant's lacked motivation to complete the badge requirements and described them as unimportant, they were coded as ineffective. The same subcodes were used for symposium effectiveness.

Case Studies

A case study methodology was used to describe in-depth, real-life phenomenon over a period of time with a set audience, to try and gather meaningful data that might not be achieved in one interview or isolated incidence (Yin 2009). Yin (2009) explains that case studies are used to "contribute to our knowledge of individual, group, organizational, social, political, and related phenomena," (p. 4). An additional strength of case studies, when compared to other research methods, is that a variety of evidence is provided through an array of techniques, such as interviews, observations, or document analysis (Yin 2009). The motivations and interests of two participants, Ryan and Sam, are highlighted to give an example of the possible experiences that Studio STEM creates to leverage interest in the service of motivation and deeper learning.

Case Study 1: Ryan

Background

Eleven-year-old Ryan currently lives in a rural community in southwest Virginia. She is a rising sixth grader at a local public middle school. She is interested in art, mathematics-oriented problem solving, and reading. Ryan has explored concepts behind oceans, rocks, light, sound, the Earth, food chains, and animals in school. Outside of school, she has participated in a program where they built Lego robots. When asked whether she likes science, her response is that she is in between loving and hating but leans toward not liking science. She aspires to be a graphic novelist primarily, but she has also considered being an architect or a video game designer. Both parents have liberal arts backgrounds with a focus on writing. In terms of technological use, she has an iPad that she uses at home and is allowed to use the computer for school research, productivity software, and playing games. Ryan also discusses how the majority of the time she enjoys group work, especially in settings similar to Studio STEM.

During the course of the four-day program, Ryan worked closely with two other females, Logan and Dakota (also pseudonyms). During the first day of program, the group focused on obtaining badges. Throughout the program, the trio would divide responsibilities or tasks democratically, assuming different roles. Dakota normally instructed to the group as to what needed to be done and collected information from the worksheets and badges. She also continually expressed her ideas by drawing on a whiteboard. Logan consistently documented the progression of the group design. Ryan was the main builder and designer of the group. Her main focus was building a solar-powered car.

Findings

Problem-Based Learning

Ryan was more motivated to build the solar car and then to complete the badges. She only completed three out of seven badges, but her formal assessment scores increased. Her assessment score went from a 41.18 to 47.06 %. Her fellow group members' scores also increased. Though she did not like the badges, she would refer to the badges to help understand the concepts to build a solar car. The group shared the same opinion on the badges because the main focus was to get the information needed to build the best solar car and not getting the most badges. As mentioned earlier, Ryan's main focus was to build a solar car, which is demonstrated by her directing the group.

> Ryan: Uhhhhhhh, not really we kind of have to focus on building the car
> Logan: We want to get our car done more but like-

She followed the design process: first by gathering information from the badges and worksheets with the help of the group and then drawing out a design of a car. She then would build the car with the help of her group and test it. If the solar car did not work, then the group would iterate to see why the design failed by learning more about the problem. For example, if the problem was with the gears, the team would revisit the gear station or Ryan would refer back to her drawings that she made at the gear station.

> Ryan: Hmmm [fiddling with Legos on car]
> Dakota: We have no idea. We are just going-
> Ryan: We're just going to try [indistinguishable]
> Dakota: - to try to get the gears to work and be more stable and then work on our presentation if all else fails
> Ryan: Here let's just try with this one. [places car on floor]
> Interviewer: Are you just going to stick with one solar panel or what are you going to go for?
> Ryan: We are going to try with one solar panel and if it works then we will have to do both

Then, the group would redesign the car and retest. This process was followed throughout the entire four-day program. Ryan was motivated by the design-based process and helped motivate her group mates to complete the solar car through problem-based learning.

In terms of the symposium, Ryan stated that she did not like presentations, but that she did ask content-related questions. Her group thought that the symposium was a great opportunity in comparison with Ryan.

> Interviewer: Do you guys like the idea of a presentation?
> Dakota: Ummm I guess its ok-
> Logan: It's a good thing to do-
> Ryan: I don't like presentations
> Dakota: It's a way of showing others what we did but I kind of think it would be easier to just show them our car, our final product and then maybe just show a few steps of how we got there-
> Logan: Well yeah-
> Dakota: Instead of making up an entire presentation and stuff
> Logan: No No our presentation [air quotes for presentation] is just showing everyone our car but what it should be…well what I think I just wish we had one day like if it was a Monday to Friday thing. I don't know. Just a little more time

The data suggests that Ryan contributed to making the presentation but participated minimally in the actual symposium. She mainly helped her group mates with the solar car during the presentation.

> Ryan: It kind of has a three-gear pattern
> Dakota: Yeah and so let's say there is one wheel here and two wheels really tight right here and a medium gear on the axil and a big gear attached to that and a small gear attached to the motor and stuff. And that failed very very badly. Terribly
> Logan: The gears were either too close or too far apart
> Dakota: So we jacked that idea. [erases drawing on whiteboard] Next instead of putting it in the back, we moved it to the front and we tried putting the gear right here- [draws what is being said]
> Logan: On the outside
> Dakota: On the outside and we tried putting it next to the wheel on the inside and both of those ideas failed also [crosses out drawings on board] Even in our moment of truth it failed. Then-
> Logan: We tried a two gear option
> Dakota: Two gear option
> Logan: Which had our biggest one on the axil

Dakota: On the axil [drawing on whiteboard] and then smallest one was attached to the motor and that one took a lot of time and a lot of effort and a lot of failure to get to but we finally finally made it work and it pulled ten eggs. And we made a little thingy on the back [pointing to the back of solar car] to hold the solar panel to balance the weight and let us show you our cart. Our cart helps the Seabirds with our design because it has a really high torque motor and low ratio gears. [Ryan puts solar car on ground; Logan tries to turn on lamp; Dakota then puts light on]
Dakota: Wait it's backwards [turns solar car around]
Logan: I often forget that. [solar cars move; indistinguishable]
Dakota: Save the seabirds and our time [attaches cart with plastic eggs in it to solar car]
[indistinguishable]
Logan: the other piece was on there. [Dakota fiddling with solar car]
Dakota: I thought this was attached
Logan: We can still just stick it on there.
[Logan turns light on then off; Ryan and Logan looking at Dakota]

New Media

Ryan utilized the iPad to draw in Notebook + throughout the duration of the program (Fig. 2). She helped collect information from other groups on what was the most effective design whether using Edmodo or walking around the space.

Ryan: Gears. [Playing with iPad drawing tricycle design] Dang it

She referred to it as "spying" on the other groups. Ryan utilized technology to the fullest; she used the iPad for both Edmodo, Notebook + application, and other applications to either further her understanding of aspects of the program or to share her ideas with the rest of the participants.

Discussion

Problem-Based Learning

Ryan's main motivator was to build a solar car to pull the "seabird" eggs. She was not motivated by the idea of saving the animals or completing the badges. As mentioned earlier, she expressed interest to build the best solar car possible and adhered closely to the engineering design process. In her case, the engineering design process played a significant role in reference to research question one. She did not specifically state, "I'm going to follow the engineering design process." Nevertheless, based on analyses of field notes and design artifacts, she engaged in a series of iterative refinements, which is at the core of the engineering process.

Through the iterative process of collecting data from tests, she was able to derive possible designs for the solar car. Normally, the group would try one design, and if it did not work, then they would redesign based on what they thought the solution to the problem was. For example, originally, the group attached the motor box directly to the wheel, which inhibited the wheel from rolling. In the next iteration, they decided that they needed to learn more about gears and then based on that information attach the motor box on top of the solar car and connect it to the wheel by gears. Deeper learning accrues from this iterative engineering process where information is gathered as needed to confirm design hypotheses.

In terms of presenting ideas to the group, each member of the group would use visuals and verbal communication to convey ideas. Normally, the communication was relayed through visuals. Ryan either would show the group through actually executing her idea or showing the group her drawings of the design. By showing her design through actually building, Dakota and Ryan tended to discuss in depth whose idea was better, sometimes coming to the conclusion that they should combine their ideas. Normally, in the end, it was resolved by what worked the best through experimentation.

New Media

Ryan integrated new media at each station, looking up information and drawing what she learned or saw. For example, one of the stations was a pulley system which she drew in her Notebook + application (Fig. 3). Ryan also played a key role in designing the solar car to be a tricycle-based design which she drew out in her Notebook + application.

Conclusion

Technology played a significant role in Ryan's learning process. She was either building, talking to group members, or on her iPad. Ryan seemed to be affected more by interacting with fellow group members, which is exemplified through multiple discussions with the group, and most of her questions were directed to peers online via Edmodo or in the studio, face-to-face. As for the engineering design process, Ryan embodied the idea of utilizing said process. Based on the findings, Ryan was motivated through technology specifically the iPad and peers. She was minimally impacted and motivated by facilitators and the badges. Ryan learned and was successful in the program based on increased assessment scores and ability to be a part of a group with a successful solar car.

Case Study 2: Sam

Background

Sam grew up in a small, rural community and is 13-year old. He is a student at a local private school where the class sizes are approximately 20 students per teacher. Sam lives with both parents and one younger sibling. Sam has a serious love for airplanes and understanding how they work. Sam has been in science classes that contained curriculum on chemistry, earth science, biology, and entomology in a formal setting. When describing personal computer use, Sam conveyed a healthy love for conducting Internet searches for "personal research" of interesting topics. Computers are mostly used only at school where Sam can write papers using a text editor, draw diagrams on a paint program, and create movies with video editing software. Sam's mother has an iPad that he can borrow to message his friends on the weekends.

> Interviewer: Some students like science, other students don't like it at all, and some are just in between. Where are you?
> Sam: I really like science, I would give it a 10 out of 10. But… I would give engineering a 7 out of 10
> Interviewer: What kind of job or career can you imagine doing when you start working?
> Sam: I wanna be in the Air Force, I want to fly to planes or be a mechanic. Drones are cool too
> Interviewer: Do you like to work in groups?
> Sam: Yes! I like to share knowledge with others. I do Boy Scouts and Lego League so I have experienced the partnership and stresses involved with group work

During the four-day program, Sam worked side by side with two other male participants, Casey and Morgan (pseudonyms). Casey clearly settled into the role of the builder, and he constantly had his hands on the Lego pieces tinkering with the prototype. Morgan took a hands-off approach to the prototype, but found his niche as the archivist, documenting each step of the process in Notebook + on the iPad, and then on Edmodo. Sam bridged the gap, in the beginning, and he designed the car in Notebook + and helped build it, but toward the end, he focused on the presentation for his team (Fig. 4). So, just about every day, the trio would collaborate at specific stations. Most of the time the trio leveraged access to a facilitator who could explain the subjects being researched more in-depth should they need.

Findings

Problem-Based Learning

From the first day of the camp, Sam and his teammates showed no intention of completing the badge station requirements in full as captured in conversations represented by excerpts below. When a topic is addressed, Sam speaks on behalf of his teammates to convey that their needs are to learn the necessities only for building a great solar car at each station. Once they learned how each station applied to their solar car, they had no need to sketch, take notes, or collaborate further on the subject matter at hand because they had the information they needed to complete the overarching goal. Seemingly, completing the goal of saving the seabirds with a strong and fast solar car was more enticing and empowering to Sam and his teammates than earning badges for every station they completed.

> Interviewer: Can you explain again why you chose to just, ya know, why you're going for the badges or not?
> Casey: [tinkering with lego motor and other pieces]
> Morgan: [typing on iPad]
> Sam: Just because we wanted to get what we needed to know. We really just wanted to do what was most valuable and what was most necessary for us
> Investigator: So why are the badges not necessary?
> Casey: It is not that they aren't necessary…
> Sam: They are necessary but they aren't the most vital, the vital information we need isn't in the badges

Each participant took a preassessment on the iPad at the beginning of the program. Then, each participant took a post-assessment at the end of program. Administering an assessment on the iPad through Edmodo contributed to the informality of the overall program. Surprisingly, Sam's preassessment score was higher than his post-assessment score. He scored a 65.1 % on the preassessment and a 50.9 % on the post-assessment.

By the end of the week, the trio had exhausted the engineering design process. There had been initial research at the stations, initial design, building, testing, redesign, and more testing that was clearly described and voiced by each team member. Casey continually reminded his teammates that this process was for prototyping, and they would be able to see the mistakes they made so that they could fix them for the next time they designed and built.

> Casey: Uhhh, gears to friction, to here, to building. [points to each table while talking about the gear station] We wanted building to be last. We will think

of the best combinations we can make and we will have time to decide on stuff
Sam: Yeah, we wanted a long time for building. [sketches on iPad]
Interviewer: So is your focus on purely what you need to build your car?
Casey: Yes

The boys' improvement in this process was visible by the last day of the program because of their successful solar car. The car donned two solar panels connected in parallel to a high-torque motor with the smallest gear ratio and could pull all of the twelve seabird eggs in the plastic cart. The trio was expressed pride of their design and presentation. Sam referred to the program, and their final design, as satisfyingly successful.

New Media

Sam knew how to use the technology because iPads were readily available for him in other environments. Sam did enjoy using Edmodo SNF as he appreciated that the online forum allowed him to share his knowledge with other participants. He frequently commented on his peers' posts that were questions about the stations, the design process, or the symposium. Sam also openly talked about how much he enjoyed using the iPad. The thing he liked the most about the technology was his ability to make a video for his team for their final presentation. He used a video editing app to produce a multimedia artifact describing his team's experience throughout the week. The final version of the video used a rock music background, an Iron Man theme, and a footage of their solar car pulling twelve seabird eggs over six inches.

Interviewer: So explain to me in what ways you used the iPad this week?
Sam: [waves at the camera, laughs, and mouths something to Casey] I, uh, used it for my presentation and I used it to take notes and pictures and videos. And I sometimes used it to soothe my boredom
Interviewer: So, how much of it was for fun and how much of it was to be productive?
Sam: [holds up his hands with his thumb and pointer finger showing a small distance, holds the hand up to his face] This much of it was fun, and this much of it was productive! [moves fingers apart to show a much larger distance]
Interviewer: So, if you had a set amount of time that you could be using it for fun and then a set amount of time to be productive, would that be better?
Sam: Mmmm… [shows an inquisitive face] No, I would rather be productive than use it for fun
Interviewer: So what would you do?
Sam: I would… I like making models and designs on the computer. [uses finger to show drawing motions on the iPad to sketch designs] That is what I would do!
Interviewer: So you would rather have no time…
Sam: Well, because that stuff is fun for me. [interjects, maybe for Interviewer to better understand]
Interviewer: What about Edmodo?
Sam: [clicks to the home screen on the iPad, clicks the Edmodo app] We used Edmodo to post our comments and things and we were able to answer questions. [clicks on a post to show the camera, begins typing a reply]

Discussion

Problem-Based Learning

Sam's group, over the course of the week, became to appreciate the value of the engineering design process. On the first day of the program, they were introduced to the challenge of saving seabirds using science and engineering. After conducting research online to approach the problem, Sam and his teammates set out on a prototyping adventure highlighted by an iterative series of failures and incremental successes. They began with sketching their designs in Notebook + (Fig. 4) and discussing what would and would not work for the materials they had available and the specifications imposed. Building and iteratively testing followed design, which gave the boys a view into how their car prototype would work and what was potentially wrong with the initial design. The building and testing steps were repeated with some research and questioning in between to bring the team to a final working design that pulled all twelve seabird eggs. Sam, Casey, and Morgan increasingly have deeper knowledge of engineering design and carried each step of the process to accomplish the goal at hand. The PBL setup for Studio STEM motivated Sam and his teammates by providing a framework by which their solar car could be iteratively designed, built, tested, and documented.

The symposium was discussed only a few times by the boys. The first time was to ask what the word "symposium" meant. The next few times were to talk about their ideas for the presentation. When the symposium details were described to the team, Casey demonstrated signs of competitiveness by telling his teammates that they must have the best presentation for the symposium, demonstrated by building the best car that could save the most seabird eggs. Sam quickly agreed by statin "awesome" presentation. The symposium allows the program to have an amount of peer accountability for the participants. Participants are responsible for the content they need to know to speak to their peers about their personal processes. Sam and his teammates obviously understand the need to have high-quality work to produce for their peers. This form of interaction between the participants and other youth, facilitators, and other adults showed to be a feature of Studio STEM that was highly motivating.

> [video plays that Sam made on iPad the previous times, Sam, Casey, and Morgan stand next to the tv projector and watch the video]
> Sam: So, umm… this is our car [holds up prototype to show audience] and as you saw in the video, it can pull all twelve eggs which was the most amount of eggs that the cart could hold and that we had. And design is just that… it has a high torque motor which is the most powerful motor then the smallest gear and the biggest gear which helps it with its power and its speed and it just works really well with solar power. We have two solar panels. [rotates car around to show the audience each part Casey is describing] And we hope it helps save the seabirds
> Morgan: Should we show them the eggs? [points to the cart full of eggs]
> Casey: Yeah. [sets down the car and picks up the cart full of eggs] So here are all the eggs and they're not empty they have plaster in them [holds up one egg to the audience] so they're kinda heavy. But it works, it has been a lot of failure, but failure is good! [audience laughs] But it finally paid off! [holds up car one last time]

New Media

In the initial interview, Sam was asked to describe his technology usage as described above. He considered the question and proceeded to report that his personal computer use overlaps entirely with his professional computer use. In other words, Sam spends very little time "messing around" on the computer or with other gaming consoles. This speaks to the lack of interest Sam had in experiencing, in full, the badge stations during the program. Sam never plays video games, so he was never motivated to "earn achievements" or to "level up" from the badges. The two other participants in Sam's group, Casey and Morgan, do enjoy playing games on the computer and on other gaming consoles, and they even still agreed with Sam about the unnecessary need to fulfill of the badges. These responses support the ineffectiveness of the badges as an extrinsic motivator in an informal learning environment.

Conclusions

Sam saw a decrease in his posttest score at the end of the program. In formal education environments, he could have been evaluated as unsuccessful in gaining a deeper learning of the science constructs. In light of Sam's documented progress in this informal learning environments, Sam should be celebrated for collaborating on a design project that succeeded to the highest standards of the program. Sam's team made it clear that their only intentions were to have a winning solar car, not to complete the badge stations in full. The challenge to save the seabirds by being able to pull all twelve eggs with a solar-powered car, PBL and the engineering design process, and the peer accountability of the symposium presentation at the end of the week were the three most effective extrinsic motivators for Sam.

Review of Case Studies

Ryan and Sam adopted similar roles in their respective teams. Sam enjoyed building and contributing to the design of their prototypes, and Ryan was motivated to incorporate her ideas into the overall design. Each participant had someone else in his or her trio that seemed to take on the primary role of building. Nevertheless, Ryan and Sam fit well into their own interest-based niche for the week. These youth understood the overarching goal of the camp: to design and build a solar car that could pull the most mass, metaphorically referred to as saving seabird eggs in the curriculum. Throughout the week, Ryan and Sam approached the curriculum of Studio STEM in similar ways. They agreed the overarching goal was larger, and more important than the badge requirements and worksheets presented at each station. Regarding the symposium, Ryan was not as interested in the presentation, while Sam was enveloped during the last day of the program with creating and editing his team's presentation. Sam seemed more motivated by the thought of peer accountability than Ryan. It is important to note that a male and a female participant each had similar feelings about some of the explicit design features that Studio STEM provided while also disagreeing about the effectiveness of other aspects.

Participants that accepted a niche throughout the week formed collaborating groups that provide interest-based learning experiences. In most groups, there was a builder, archivist, and collector. The builder was in charge of building the structure of the solar car. In Ryan's case, she was the builder, but she also designed the structure she wanted with the help of her group. In Sam's group, he was the collector. Sam had his hand in the design process, the note taking, and the presentation. The archivist was normally the group member who took pictures and videos and posted updates about the group on Edmodo. This was normal so that the youth's peers could share in the new information that was found. In a couple of instances, the archivist also helped create the presentation. The collector was a participant who helped each team member but mainly gathered information about the concepts behind the solar car and most likely had a part in the design of the car, and this participant was also known to be heavily involved in the presentation. Even though each member of the different groups took on specific roles, each were flexible and at times interchangeable, but they all took on roles based on their interests.

Ryan was motivated more by the new media that was made available to the program participants, and as stated before, Sam was not as highly affected by this technology. Ryan had no problems learning her way around the iPad since she had an iPad mini at home. Due to Ryan's technological exposure at home, she was able to apply that knowledge to the program without having extreme difficulty and limited learning curve. Both she and Sam had a few problems with Edmodo but were able to figure it out with the help of peers and facilitators. It seemed that every participant had to take time to learn about Edmodo because of the lack of exposure prior to the program; Sam and Ryan shared that difficulty with the entire group.

Overall, Edmodo was a highly used platform during Studio STEM program. The participants appeared motivated to post and respond to peers throughout the week. They also enjoyed personalizing their profiles by changing the profile picture and the background for their profile. A notable difficulty with Edmodo was posting pictures to the forum. There was a small learning curve that all participants had to endure mostly because they had never experienced Edmodo prior to the camp. Also, it seemed as though some participants preferred to use the supplied technology to distract themselves or their peers. Technology, such as iPads, has features that can be very educational and helpful but that can also be very distracting. For example, some participants would use a camera app on the iPad to take pictures to showcase their solar cars, while others would use it to take funny pictures of their faces to make other participants laugh.

In general, the entire group of fourteen youth enjoyed focusing on the global impact portion of saving animals and the immediate goal of making a functioning solar car. The badges were enticing to a few as short-term motivators to get participants started in the program. Nevertheless, once the participants began to understand the events that were going to take place and once they had the goals explained to them, they focused more on the long-term, more influential features of Studio STEM. Most teams claimed that they would much rather save more seabirds by having a powerful, working solar car than completing all of the badge requirements for the entire week. Most of the teams agreed that if they had time left after finalizing their solar car design, they would return to the badge stations to finish up any requirements they had skipped.

Conclusions

This research set out to examine which features of an informal STEM learning environment fostered motivation in middle school youth. Connected learning served as a guide for analysis and description. The investigation addressed the design features of an out-of-school curriculum that formal education could consider to form educational experiences that cultivate the inherent interests and peer cultures of youth. The goal of this type approach could allow youth to tap interests in a more intentional, academic ways that could promote deeper learning in STEM domains. Overall, the case studies of one middle-school-age girl and one middle-school-age boy provided insight into different responses to and effects of attempts to leverage interest and peer culture. As mentioned above, Ryan's motivation primarily stemmed from her desire to build a successful solar car to rescue seabird eggs where Sam's motivation was to complete the symposium and the overall task of the program to save seabird eggs by building a successful solar car. Problem solving, new media, and peer interaction as designed features of Studio STEM elicited evidence of stimulating interest in STEM for deeper learning.

Teachers in formal environments could adapt an informal curriculum to match their needs as an educator. By understanding the features of this particular curriculum that successfully spurred on participants, they can begin to make decisions in their own classrooms that will have an impact on participants' interest in STEM subjects. The collaborative efforts that participants put forth show the importance of problem- and interest-based learning on the motivations of participants within the program. With that, most of the participants enjoyed peer interaction and deemed it necessary for the overarching goal to be accomplished as evidenced by the symposium, postings on Edmodo, and daily verbal and nonverbal interaction. Having the interaction extend to Edmodo was necessary for supporting the collaborative efforts between participants in the entire program by allowing each participant to use other participants as resources. Studio STEM gave each participant a global outlook, keeping them in touch with the world while supporting their own personal interests and growing their intrinsic motivations.

The connected learning model was used as a guide to help articulate the research and design efforts to integrate multiple groups and constraints such as education, popular culture, home, and community. By addressing these constraints and offering a problem-based curriculum in a free-choice environment, the connected learning model was implemented by offering participants the time, space, and permission to pique their interest in a problem using multiple types of entry points for engaging and motivating them to persist in Save the Seabirds. The connected learning model helped Studio STEM focus educational attention on supporting interest-driven learning and took advantage of the digital network and online resources that exist to support the program.

Future research would benefit from using mixed methods to investigate the motivations of program participants in a more formal environment. This would provide researchers more insight into the features of learning environments that truly motivate participants. In an after-school environment, for example, participants have just finished a long day of school. Then, they come to Studio STEM to learn even more. This produces a more formal environment solely because the program may seem like an extension of the participants' regular school day. Collecting information from the parents about their viewpoint on technological use and if parental controls are placed on participants could give more insight into each participants' reliance on technology. Another key approach could be studying more in depth the gender separation in STEM learning environments (Blickenstaff 2005). Overall, making these adjustments could provide more information in regard to improving the program.

Acknowledgments This material is based on work supported by the National Science Foundation (NSF) under Grants DRL 1029756 and 1239959, and the Institute for Creativity, Arts and Technology (ICAT) and the Institute for Society, Culture and Environment (ISCE) at Virginia Tech. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of sponsors. Studio STEM (http://studiostem.org) at Virginia Tech includes the authors, and a talented team of coinvestigators (Drs. Brett Jones, Christine Schnittka, and Carol Brandt), and graduate and undergraduate research assistants. We thank Ms. Samantha Won, doctoral student in the Department of Learning Sciences and Technologies, Virginia Tech, for providing valuable feedback on earlier versions of the manuscript.

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