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STEM Related After-School Program Activities and Associated Outcomes on Student Learning

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Abstract

This study explores the characteristics of after-school program activities at a charter school in the Southeast US highlighting students' experiences with and gains from these after-school program activities. A qualitative case study design was employed to understand students' views and opinions regarding the activities and their learning trajectories. Study data were collected through formal and informal observations, one-on-one semi-structured interviews, and field notes. The study's findings indicated that such activities emphasize open-ended and collaborative scientific investigations in Science, Technology, Engineering, and Mathematics (STEM) fields and provided an arena for students to demonstrate various uses of 21st century skills. We have described and explained: (a) the importance of collaborative learning groups, (b) the popularity of after-school program activities, (c) interest in STEM fields, and (d) activities' contribution to developing 21st century skills. These findings show that STEM related activities have the potential to promote collaborative learning and inquiry as well as to contribute to the development of 21st century skills. These findings have also been discussed in light of how STEM related after-school program activities support students' learning.

Key Words

After-school Program Activities, Engineering and Mathematics (STEM) Education, Science, Technology.

Science, Technology, Engineering, and Mathematics (STEM) education is a newly emerged paradigm which focuses mostly on science and mathematics disciplines, but which also includes technology and engineering (Bybee, 2010b). STEM education is considered a means to help individuals develop different strategies in order to solve interdisciplinary problems and gain skills and knowledge in order to sustain scientific leadership and economic growth in the United States (Lacey & Wright, 2009). Recent reports indicate that the next generation is not prepared to respond either to current demands or to those of the future (National Research Council [NRC], 2011). International indicators (e.g., TIMMS and PISA) report that US students exhibit a low level of performance in mathematics and science. In addition, there has been witnessed a decrease in the number of graduates from STEM fields (NRC, 2011;

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Schmidt, 2011). Individuals trained for STEM-related professions have become insufficient, both in terms of overall quantity and in quality of skills, to meet the country's demands (NRC, 2011). Therefore, these findings represent a call to initiate STEM education and increase career interest in STEM fields.

To increase students' interest in STEM subjects and to cultivate STEM literacy, many initiatives and efforts have been launched and implemented. The US government initiated a program, "Educate to Innovate," whose aim is to encourage student participation in STEM-related activities and to incite an interest in STEM-related careers (Obama, 2009). Studies on cultivating STEM literacy have revealed that the science and mathematics components of STEM have gained prominence in facilitating discovery and innovation in a society when compared to the engineering and technology components (Lantz, 2009). Yet, many researchers have integrated engineering topics in both middle and high school curricula (Apedoe, Reynolds, Ellefson, & Schunn, 2008; Cunningham, Knight, Carlsen, & Kelly, 2007; Fortus, Krajcik, Dershimer, Marx, & Mamlok-Naaman, 2005; Mehalik, Doppelt, & Schunn, 2008; National Academy of Engineering [NAE] & NRC, 2009; Wendell et al., 2010). For instance, Apedoe et al. (2008) developed an eight-week high school curriculum unit that uses engineering design to teach chemical concepts. They helped students understand atomic interactions, reactions, and energy changes in reactions through the engineering design process. Cunningham et al. (2007) developed a professional development unite for in-service teachers to experiment with the engineering design process in which the teachers were involved in the development of the unit's lessons plans. Wendell et al. (2010) integrated engineering design into science curriculum through the use of LEGO Mindstorm Kits. They found that by using LEGO Mindstorm Kits helped students learn science concepts better when compared to traditional science instruction. In line with these attempts, certain education standards emphasize the interrelationships among science, mathematics, engineering, and technology (International Technology Education Association [ITEA], 1999; Massachusetts Department of Education, 2006). Having students participate in STEM activities is considered a way to increase interest in STEM subjects and to foster STEM literacy (Kauffmann, Hall, Batts, Bosse, & Moses, 2009; Sullivan, 2008).

Individuals are expected to gain a variety of problem solving skills and to meet the needs of society within this century. These needs may lead to a change in educational standards and in the quality of the education system. In this regard, a number of researchers have defined and developed 21st century skills, relating these skills to social, economic, cultural, and political issues in today's competitive world. They have listed 21st century skills as (a) critical thinking and problem solving, (b) collaboration and leadership, (c) agility and adaptability, (d) initiative and entrepreneurialism, (e) effective oral and written communication, (f) accessing and analyzing data, and (g) curiosity and imagination (Association for Career and Technical Education, National Association of State Directors of Career Technical Education Consortium and Partnership for 21st Century Skills, 2010; Wagner, 2008). Other researchers have designated 21st century skills as adaptability, complex communication/social skills, and non-routine problem solving, self-management/self-development, and systems thinking (Bybee, 2010a; Windschitl, 2009). Cultivating STEM literacy is associated with developing and using 21st century skills in individuals' daily life endeavors. Through the development of these skills, the next generation will be equipped with the skills needed to solve their daily problems and to contribute to meeting the ever-changing needs of their society. Thus, the acquisition of these skills further increases the importance of STEM literacy.

After-School Programs and Activities

A variety of programs alternative to traditional schooling have gained prominence in education communities (Bucknavage & Worrell, 2005). Individuals involved in after-school program activities generate solutions to daily life problems presented in a simple context in which participants construct their own understanding (Cicek, 2012; Maden, 2012). At first glance, after- school programs are associated with science clubs and visits to museums, zoos, planetariums, national parks, and natural settings (Sahin, 2013; Şimşek, 2011). In addition to these venues, after school programs may also include robotics, science fairs, Science Olympiads, and Mathematics Olympiads (Sahin, 2013).

After-school programs are a means to "foster interpersonal competence, help define life goals, and promote educational success" as long as the aims and content of activities offered in after-school programs are well defined (Wirt, 2011, p. 48). Through after-school programs, students learn how to collaborate and communicate with their peers and teachers in ways different from their interactions in regular classrooms (Mahoney, Cairns, & Farmer, 2003). After-school program activities have become a means for students to better understand scientific concepts, processes, and procedures (McGee-Brown, Martin, Monsaas, & Stombler, 2003). These activities allow them to acquire scientific inquiry skills, develop scientific reasoning (Abernathy & Vineyard, 2001; Bernard, 2005; Fisanick, 2010), and improve their communication skills (Czerniak & Lumpe, 1996; Grote, 1995). These activities contribute to higher science achievement scores and motivate students to work together and share their ideas, experience, and knowledge with each other. In turn, students take ownership of their ideas and learning, while also cultivating a sense of belonging to a group (Abernathy & Vineyard, 2001). In this regard, students who view themselves as members of a learning community find themselves more motivated and more able to commit themselves to the activities they are to perform.

After-school program activities also have a role on prompting students to join competition-oriented science fairs and Science Olympiads. Students participating in these activities are informed that they will compete with other students from other communities throughout the semester. Such an atmosphere of competition encourages students and their teachers to build collaborative partnerships with graduate students and scientists. In turn, this can help them develop multi-memberships (Bunderson & Anderson, 1996). Thus, after-school program activities can act as a bridge connecting students to individuals in different communities in order to accomplish their goals.

21st Century Skills

21st century skills have become prominent in various disciplines, not limited simply to the physical sciences, but which are also prominent in the social sciences and humanities. Yet due to its common use, determining a general definition for these skills is made more challenging. Silva (2008) stated:

> For all of the talk about 21st century skills, trying to figure out what they really are is not easy. The term 21st century skills is everywhere and used to describe pretty much every imaginable skill or attribute: soft skills, life skills, key skills, inter-personal skills, workforce skills, non-cognitive skills the list of skills goes on and on (p. 1).

The Partnership for 21st Century Skills (2011) has advocated the use of 21st century skills as a means for increasing students' readiness to solve real-world problems. This partnership designated 21st century skills as *critical thinking, problem solving, communication, collaboration, creativity,* and *innovation*. Yet both before and after these skills were delineated, a number of studies had described these skills, their equivalents, and their components. For instance, Wagner (2008) pointed to seven skills emerged from conversations among several hundred businesses, nonprofit, philanthropic, and education leaders such as Dell, Siemens, and Apple. It was reported that the next generation should master the following skills in order to thrive in the new world of work: (a) critical thinking and problem solving, (b) collaboration and leadership, (c) agility and adaptability, (d) initiative and entrepreneurialism, (e) effective oral and written communication, (f) accessing and analyzing data, and (g) curiosity and imagination. Thus, these skills are considered invaluable to cultivate the next generation who play a significant role in making social, economic, cultural, and political decisions (NRC, 2009).

Interest in STEM Fields

Interest in STEM is defined as an individual's positive attitudes toward science, technology, engineering, and mathematics subjects; in other words, an individual who has developed an interest in the content area of these subjects and activities. In turn, this interest becomes a stimulus for them to pursue any of the STEM subjects in their future career (Buxton, 2001). Studies claim that allowing students to engage in authentic learning activities as they learn STEM subjects at school enhances their early interest in STEM (Dabney et al., 2012; Maltese & Tai, 2010; Tindall & Hamil, 2004). Yet, activities disconnected from real-world problems and students' daily life experiences act to decrease their interest in STEM (Cleaves, 2005; Lindahl, 2007). To trigger individuals' interest in STEM, many researchers suggest offering after-school program activities coupled with supplementary schooling experiences (Bell, Lewenstein, Shouse, & Feder, 2009; NRC, 2009; Zoldosova & Prokop, 2006). It appears that after-school program activities have the potential to provide students with the sufficient time and space needed to engage in collaborative and open-ended projects in STEM fields without the constraints of a structured school curriculum.

There are other perspectives whose aim is to promote STEM literacy and to boost individuals' interest in STEM subjects. The extant studies point to focusing on advanced coursework completion (Adelman, 2006; Tyson, Lee, Borman, & Hanson, 2007), enhancing student interest in STEM fields (Cleaves, 2005), and providing in-class experiences with STEM-related activities (Cleaves, 2005; Munro & Elsom, 2000). In addition, public schools have revised their curricula and charter schools in particular have begun to offer after-school programs for K-12 low-income students to instill proficiency in STEM subjects and to facilitate their development of 21st century skills (Jerald, 2009; Wirt, 2011). Yet, there is little research exploring STEM-related after-school programs that supplement student classroom experiences (Wirt, 2011). In this study, we have aimed to characterize STEM-related activities offered in an after-school program at a small-scale charter school and to explicate students' views toward these activities in terms of their learning progress, competence, and interest in pursuing STEM careers. By doing so, we have ventured to study the potential impact of such activities on student developing of STEM identities, their interest in pursuing STEM careers, and then relating these outcomes to STEM literacy.

Method

Charter-school Setting

Charter schools are a type of public schools generally defined as a "publicly funded, nonsectarian school that operates under a written contract, or charter, from an authorizing agency such as a local or state board" (Texas Education Agency [TEA], 2006, p. 1). Charter schools are funded by a state, yet run independently in the sense that they are left to hire their own teachers and staff as well as manage their own budget.

Harmony Public Schools (HPS), where the participating charter school was selected in this study, is a charter school system consisting of 40 schools serving more than 25,000 students as of October 2013; each campus with their own building level administration. Harmony students were female (51 percent), Hispanic (47 percent), and low socio-economic status (56 percent free or reduced-cost lunch). HPS is a Texas-based non-profit organization. The focus of HPS is on mathematics, science, engineering and computer technologies. Students attending these schools are encouraged to choose an after-school program activity relevant to STEM subjects. Staff members do not dictate students' participations in these activities. Student participation is voluntary and mostly driven by their interest and individual commitment. In other words, students are free to choose an activity in which to participate and may revise their choice within the first two weeks of the same semester. If a student were to quit participating in an activity, s/he would not be penalized.

The participating charter school's student population from kindergarten to high school totaled two hundred forty-nine. Among these students, 50% of them received free, 9% of them received reduced-priced lunch, and 21% received paid lunch. Students' demographics were 33% White, 51% Hispanic, 13% African-American, and 3% Asian (Indian) and Native Americans. This school employed 24 teachers; each with varying years of teaching experience: seven teachers were first year teachers; ten teachers had between 2 and 5 years of teaching experience; four teachers had between 5 and 10; and three teachers had more than 10 years of teaching experience. Teachers were encouraged to organize and manage at least one after-school program activity. Once activities were determined, students were made aware of these activities and were encouraged to enroll in whichever activities interested them. On average, more than half of the teachers led these activities every year. When the study data were collected, seven of them were responsible for organizing and leading STEM-related activities.

STEM Related Activities

Six STEM related activities—offered through after-school program at the charter school— were characterized: *Robotics, MATHCOUNTS, American Mathematics Contest (AMC), Science Olympiad, Science Fair,* and *University Interscholastic League (UIL)*. *Robotics* activities included designing, programming, and problem solving activities through ready-made computer software. For example, the students worked in collaboration to build, design, and test their robot model. They presented their design to the audience during competitions. *MATHCOUNTS* activities aimed to increase student's achievement in mathematics as well as to allow them to realize the connection between mathematics and their daily life, including in their relationships with their parents, school, and society. In *MATHCOUNTS* activities, group members practiced basic problem solving strategies (e.g., identifying the problem, devising a plan, and decision making for the possible options) to develop their problem-solving skills. *AMC* endeavored to increase student's interest in mathematics and to help them hone their problem-solving skills. *AMC* activities included a comprehensive presentation of elementary and ingenious problem solving techniques including plane and transformational geometries, coloring proof, number theory, and so on. Although there was a science fair organized at the school level, *Science Olympiad* extended its effectiveness as student participants were expected to participate in specific projects determined by the Science Olympiad committee and then compete with other competitors from other schools. Selected groups were expected to participate in a Statewide Olympiad held at a university campus. The student groups were to present their projects to a group of judges in competition with groups from various schools within the state. The judges included faculty members, researchers, and graduate students in the field; thereby creating the expectation that student presentation should be professional and academic. *Science Fair* was organized at four different levels: the school level, the regional level, the state level, and the international level. Successful projects were expected to compete at the subsequent level. The *UIL* was offered to students in the form of challenging and rigorous academic contests in various subjects including calculator and computer applications, mathematics, number sense, and science from elementary, middle, and high school levels.

Participants

There were a total of 146 students participating in the after-school program activities between grades 4 and 12. Out of the 146 students, 17 students participated in *Robotics* activities and nine students participated in *MATHCOUNTS* activities. Six students attended *AMC* activities, 25 students partook in *Science Olympiad,* and 8 students took part in *UIL* science activities. Yet, all 146 students participated in the science fair held within the school.

Ten of these students were purposively selected. These students had previously participated in after-school program activities for at least one-year previously and also participated in more than one activity as illustrated in Table 1. Of these 10 participants, 9 chose in *Robotics*, 7 chose *MATHCOUNTS*, 4 chose *AMC*, 6 chose *Science Olympiad*, and 6 chose *UIL*. All 10 students participated in the science fair held at the school. Nine of the 10 participants were male and one was female. Although there were several female students participating in STEM related activities, we were able to hold an interview with only one of them. We should have reached more female participants in order to learn and explain their views and opinions of STEM related activities in more detail.

Data Collection and Analysis

In this case study, data were collected through observations, field-notes, and interviews. The second author employed observations as he mentored two student groups for Science Olympiad: (a) water bottle rocket design and (b) tower design. Students in both groups were expected to follow the criteria outlined by the Science Olympiad committee at the regional level to design their models. The students were expected to follow the criteria outlined by the Science Olympiad committee at the regional level. However, they were free to design their own model. The researcher met with the group members designing water rockets on weekends and with group members designing towers on weekdays. He worked with them for an excess of two and a half months. During his observations, he used Wenger's notion of communities of practice notion with its three indicators—joint enterprise, shared repertoire, and mutual engagement (Wenger, 1998) as a lens to examine the social structure of the two groups (see Appendix 1).

Table 1.
Student by Grade, Activity, Year Experience, and Gender

Name	Grade	Activities (Year experience)	Gender
Student 1	9	R(4), MC(4), SF(4), AMC(1), SO(1), UIL(3)	M
Student 2	9	R(4), MC(4), SF(4), AMC(1), SO(1), UIL(3)	M
Student 3	9	R(3), MC(3), SF(3), AMC(1), SO(1), UIL(2)	M
Student 4	9	R(4), MC(4), SF(4), AMC(1), SO(1), UIL(3)	M
Student 5	7	R(3), SF(4), SO(1)	M
Student 6	7	R(1), MC(1),, SF(3) SO(1), UIL(1)	M
Student 7	6	R(1), MC(1), SF(3)	M
Student 8	6	R(1), SF(1)	M
Student 9	5	MC(1), SF(1), UIL(1)	F
Student 10	5	R(1), MC(1), SF(2)	M

Notes: Values in parenthesis indicate the number of years students have been in those clubs.
F= Female, M= Male
R=Robotics, MC=MATHCOUNTS, SF=Science Fair, AMC=American Mathematics Competition, SO=Science Olympiad, UIL=University Interscholastic League

Throughout his mentoring, he took field-notes after the meetings. He included students' efforts, feelings, and interactions in his daily journals. His observations and experiences with the two groups were supplemented with interviews in tandem with data analyses. Students participated in after-school program activities, initially spending two hours a week and then three hours later. The amount of time spent together in a week increased as the competition day approached. Throughout the preparation, although their mentor mostly guided student engagement in the activities, parents were sometimes involved in their work to observe their children's effort. Generally, competitions are held in different cities in which students participated along with their mentor and parents. During their trip to competition sites, they travelled with their teachers, which provided them with additional time and opportunity to interact with them.

Semi-structured interviews were conducted with ten students in order to explore their views, beliefs, and experiences related with STEM-related after-school program activities. In these interviews, open-ended questions were asked to ascertain what types of activities the students were offered and to what extent the students benefited from these activities, in terms of both in-school and outside of school performance (Creswell, 2007). We attached the interview protocol in Appendix 2. Furthermore, the study explored in what ways these activities helped the students develop 21st century skills and how they encouraged students to pursue a career in STEM fields. Also, the study findings were used to discuss and recommend both the potentials of these activities and which skills act to further cultivate STEM literacy.

Each student was interviewed in person to explore their perspectives on the offered activities. These interviews were recorded and transcribed verbatim (Creswell, 2007), and triangulated with observations and field notes. Their responses were coded using Nueman's (2000) three phase coding system. During the first phase of coding, an initial scan of the data was performed by the first author highlighting words or phrases used by the participants and located initial themes. Next, the main themes that emerged through collaborative analysis processes were decided upon and linked to the purpose of the study. In the second phase, the study focused on connecting themes and on finding links within the data. In the final phase, the data were reread and the final themes were audited by the other authors. To establish credibility and dependability, field notes, observations, and interviews were interrelated and triangulated (Creswell, 2007). During this process, we confirmed the findings of the observations and field notes with the interviews and found that triangulation significantly helped us extend the scope of our findings.

Findings

Four themes emerged from our data analysis are: (a) the importance of collaborative learning groups; (b) the popularity of after-school program activities, (c) interest in STEM fields and (d) activities' contribution to developing 21st century skills.

Importance of Collaborative Learning Groups

Our analysis indicated that collaborative learning groups are important to accomplish the activity goal as the students were engaged with the after-school program activities. In each of the six different activity categories, we observed the emergence of various student-composed groups. For instance, while there were two middle school students interested in designing a water bottle rocket for Science Olympiad, four high school students collaboratively worked on designing a tower for Science Olympiad. The students who participated in the school-level science fair were expected to work alone and were encouraged to take the ownership of their project. The students who participated in MATHCOUNTS were also encouraged to work alone since they were expected to compete with other individual participants in the competition. The main reason that students formed a group was because they shared a common interest with each other and because they had already known each other.

In each activity group, the students were mentored by their teachers and outsiders (e.g., graduate students). For example, their computer science teacher mentored students participating in the robotics. This group included students ranging from 4th to 10th graders. Although these students were to compete with different grade levels, all graders would be evaluated together during the competition. Therefore, their mentor encouraged them to work together.

Regardless of the activity in which groups participated, weekly meetings provided a social platform for the students to work in a collaborative manner. Through these meetings, the students developed more interactions with their mentor as well as with their fellow group members. The students working together believed that working in a group offered greater opportunities for them to design, build, test, and rebuild their models before the competition. These students felt fortunate since they were able to collaborate with their close friends while working on the project which was itself instrumental in teaching them both their own and their friends' strengths and weaknesses. By working in a group or a team, each member helped to compensate for the weaknesses of the others thereby increasing their ability to complete the tasks assigned to them. The students also expressed that they believed that learning occurred as a result of their mutual collaboration. As such, it may be asserted that collaboration contributed to the students' learning from each other, to their understanding the different aspects of a specific task at hand, and more importantly to the successful accomplishment of the tasks assigned to them. To illustrate this point, a number of student statements from the interviews are noteworthy:

"Like from their [other students'] skills, you learn better and they learn from your skills and you can both become better at what you have been doing. In robotics, I was good at programming and I learned how to program somewhat from him [Student 2]." (Student 4)

"[The] benefits of working in a group are that we all have ideas and we probably put all it together and we can learn from each other's ideas and we can make better robots. Making a better robot is kind of the point of working together." (Student 7)

"It [collective working] teaches how to work with a team instead of working by myself. It helps you learn to help others, accept help from others…You can accomplish more with friends." (Student 6)

Working in a group was also a means for the students to interact together and maintain the existence and integrity of their group. Because they were expected to compete with other individuals in competitions, they needed to specify and develop clear norms in order to continue to perform their contextual activities. Yet, their norms, some of which developed over time, were not codified in written form but were instead developed as a result of meetings and negotiations between students and their mentor. After deciding upon a norm however, each student in any given group was then expected to adopt it over time. For instance, mandatory participation of group meetings was decided upon as one of the norms, the adoption and implementation of which being crucial for a student to retain his or her membership to the group since not to participate in such meetings would mean not to complete any number of assigned tasks. One of the groups building water rocket models consisted of four students at the beginning, but because their weekly meetings were held during weekends, two students missed several meetings leaving the other two students to decide how to design a model, what kind of materials were needed, and how to test it. As such, the missing students were kindly reminded of their obligation to participate in weekly meetings. However, these two students left the group since they had other meetings to attend at the same time. The first two continuously participated in meetings and engaged in activities, which in turn enabled them to retain their group membership which thereby allowed them to develop a feeling of collective belonging.

As the students performed their activities in each meeting, they developed further norms, such as respecting and listening to peers' ideas and thoughts as well as trusting each other, regardless of what differences they may have. Becoming familiar with and applying these norms was *sine qua non* for their learning progress as well as for reaching their mutual goal. Sharing their experiences, knowledge, and competences became a way to collaborate with each other thereby boosting their readiness for the competition. Noteworthy statements pertaining to this follow:

"You can get things done faster, and sometimes a person in the group may do things you do not know and you learn from others. I did not know what MATHCOUNTS was about and I learned from him [Student 7] because he has been in the group for a while." (Student 9)

"If you do not know, you ask someone about it and get help. We work a lot. You socialize with the others. You have to accept that it may not always be your idea. You have to ask the other's ideas." (Student 6)

"They taught me a lot of things in science and things that I did not know before. They taught me everyone is different. I guess because everyone has different personality." (Student 3)

Popularity of After-school Program Activities

We found that STEM-related after-school program activities differed from regular classroom activities in such a way that allowed students to learn from the task itself because regular school works mostly focused on preparing students for standardized testing. These activities were more popular among the students as compared to the regular classroom activities, such as completing quizzes and worksheets. It is not only because these activities were more open-ended, but also because they allowed for more uncertainty and commitment. Uncertainty encouraged students to engage in activities and to increase their level of commitment. In addition, students participating in these activities were expected to attend competitions where they encountered a variety of requirements and restrictions placed on them while they worked to develop their own projects. For instance, they were required to use materials specifically determined by the competition organization. In Science Olympiad for example, the students who designed their own tower were allowed to use balsa wood and follow the given instructions to build a tower. Yet, such requirements were not a barrier impeding them from developing their own ideas or restricting levels of commitment and uncertainty since there were many possibilities left to the students' discretion in the actual design of the tower. Designing, building, and testing their tower models enabled them to reach their best, but they needed to redesign, rebuild, and re-test the model after many trials, which allowed them to prepare themselves for the competition.

Their activities also consisted of two main components: hands-on and minds-on. Students who designed a tower model employed both aspects simultaneously. Mutual negotiation and collaboration helped them follow the design-build-test-revise cycle before the competition date. Furthermore, since each group had selected a leader, he or she was considered to have a greater support role whose ideas were respected by all members of the group. The lead student did not control the other students' activity; instead he or she acted as a manager directing and coordinating the other students in such a way that they would make mutual progress. Different ideas and experiences were shared by each group member and the collective work that emerged as a result of the after-school program activities and during the competition was a milestone in their learning progress.

The activities gained popularity among the students because they were not grade-oriented thereby allowing them to feel more comfortable and enjoy what they were doing. However, they did not participate in these activities merely to "have fun." They had a schedule to follow and activities to perform in order to be able to participate in and win the competition. Moreover, they were aware that they were performing tasks to succeed in the competition. Still, a general feeling of flexibility and joyfulness motivated them in their pursuits and endeavors. Collaborating with their close friends in a specific activity made them feel fortunate, which in turn increased their level of commitment and sense of accomplishment in their task. To elaborate, the majority of students explained why they favored after-school program activities over regular classroom activities:

"Definitely there was a difference [between the regular classroom activities and the after school activities]. These [after school program activities] were a little more laid back and a little more fun and enjoyable. And the math and science activities, you are more trying to get things done and learn. I would probably go with the after school program activities." (Student 5)

"We had a lot of fun. For example, robotics is really a fun type of programming; you build a robot out of a scratch. In MATHCOUNTS, they taught us how to do things with fun. They did not bore us to the death." (Student 1)

"I enjoyed robotics a lot because I got to have fun with my friends. I was be able to do stuff I would not be able to do in regular classroom hours." (Student 7)

The after-school program activities were more challenging in comparison to the regular classroom activities since the students were required to use different kinds of materials to prepare their projects in the after-school program activities. Yet, although students were expected to decide upon and use specific materials in light of the competition requirements, they were encouraged to make their own decisions through mutual negotiations between students and their mentor as well as among the other group members. These negotiations acted as a means to come to agreements concerning which materials would be needed. However, their regular classroom activities, particularly laboratory activities, allowed them to use only the predetermined materials provided by their teacher as explicitly stated on a lab sheet. Therefore, the after-school program activities motivated students to bring their ideas to the fore and discuss them, and subsequently to finalize their decisions in a group.

Interest in STEM Fields

Data analyses revealed that STEM related after-school program activities increased participating students' interest in STEM majors and encouraged them to pursue science and engineering related careers. We found that there were three reasons for that increase. The first being was that these activities were considered more appealing and comprehensive. The second reason was that the school had developed a mission to encourage its students to pursue their career in STEM field after high school graduation. To illustrate, the following statements by students are noteworthy:

"Before I entered HSA, I was thinking more towards law or the medical field. Once I got into Harmony, it has switched my path from law [or] business more towards engineering. Chemical or civil engineering." (Student 1)

"After the science fair and robotics stuff, I began considering computer science or engineering and such." (Student 4)

"[My interest] changed [from] an entomologist to a type of engineer…a game engineer. Maybe concept art engineering." (Student 7)

The third of the reasons behind an increased interest in STEM was that by being fully engaged in the activities offered, the students gained a sense of ownership – both in terms of the ideas used and their project as a whole. They also reported feeling more productive, successful, and happy. For instance, student 7 reported that although he had always been successful in his classes before having participated in an afterschool activity, after he participated in both the MATHCOUNTS and Robotics activities, he experienced an even greater increase in his math scores. Such an experience convinced him that he was capable of pursuing a career in engineering in the future because he had led the robotics activity group, had gained experienced to deal with robotic design, and had developed a sense of ownership for the design itself. Furthermore, using their design in the subsequent competition encouraged him to develop even more positive interest toward STEM-related subjects (Barnes, 2002; Weinberg, White, Karacal, Engel, & Hu, 2005). In his interview, he stated:

"In MATHCOUNTS, I wanted to learn more because I was not doing well in mathematics and I improved my math scores a lot [after participating in this activity]. In Robotics, I wanted to have fun. I learned how…to build a team robot. It helped me be able to analyze other robots to see how they are made." (Student 7)

After-school Program Activities Contributing to the Development of 21st Century Skills

Our analysis has revealed that the after-school program activities allowed students to acquire complex communication and collaboration skills, two skills considered under the umbrella of 21st century skills.

Complex Communication Skills: The after-school program activities were performed through ongoing interactions between students and their mentors (e.g., a teacher and a graduate student). The students were mentored in different ways of performing their tasks and how to progress from stage to stage of the project. Throughout these activities, the students in groups brought different ideas and concepts to the table in order to alleviate and solve their concerns, issues, and problems. Mutual negotiations among the group members encouraged them to share the ideas and experiences that they had previously used to resolve their own problems with their group members. They agreed on mutual goals as well as how to design and present their project during the competitions.

Their tasks were not only limited to their investigations, but also included the ability to present their project's results and findings effectively to an audience or judge. They were reminded by their mentors to have their presentations prepared if they desired to win a competition. They shared their responsibility in presenting specific parts of their project. Yet, they also encountered disagreements and conflicts during their investigations and negotiations concerning who was accountable for what during the actual presentation. Their joint purpose, to win the competition, motivated them to overcome any disagreement or conflict by talking and listening to all parties involved, and then by respecting and trusting in each other's competence and experience as well as by identifying possible alternatives to complete the task in question. In their interviews, they stated:

"We talked about it and found out which one is the best way to go. What was the middle way to go? We did what was best for the team." (Student 1)

"Usually, we probably tried to test both to see which one worked better or we would combine two ideas to see how it works." (Student 3)

"One thing, probably, listening to people's ideas, is that you should not always just assume yours is correct. Also not assuming their ideas are wrong because they are different than yours. Try it… mainly our group members were disagreeing with the coach/teacher because we thought ours was just fine how it was. Finally, we did and we let them do their ideas and let then build it how they wanted to build." (Student 4)

"We would go with someone's idea first and if it was not stable enough because we had little practices with somebody else's robot. If it would come off, then, we would try another person's idea to get around that problem." (Student 8)

The interactions between the group members and outsiders (e.g., graduate students or mentors) enabled them to use and develop communication skills applicable to real-world contexts. To illustrate, they stated:

"The Science fair helped me on my presentation skills and helped me to get ready for everyday job applications; like how to present myself, how to communicate with others…the science fair helped me represent myself, made me bold and present myself." (Student 1)

"[Social skills] are important too because if you have the exact same computer skills with another job candidate, then the one with the better social skills will get the job." (Student 2)

"You develop social skills and interactions…. that [help you] learn better in class and make [it]… easier to learn in class." (Student 3)

"I can communicate better…I understood that certain things grow or change over time…thanks to the club I learned these." (Student 5)

Collaboration Skills: The after-school program activities became a means for the students to work together with their friends. Working together was not mandatory for each student, but they were motivated to collaborate with their group members as it would provide them with the opportunity to learn something new from each other. They obtained different perspectives to make progress in their project. Working together provided them with an experience to understand their own, as well as each other's, strengths and weaknesses by which enabled them to solve the problems they faced and to reach a common goal. They expressed in what ways collaboration contributed to their ability to solve problems they might face in the real-world:

For the group projects, it [collaboration] helped us know each other better." (Student 2)

You need to be able to collaborate with everyone and because it is not just one person but because it is everyone in the world and you have to be able to work together and you need to see things from big perspectives to be able to see the whole world, not just the area you are in." (Student 3)

We probably put all it together and we can learn from each other's ideas and we can make better robots. Making a better robot is kind of the point of working together." (Student 8)

You [can] have people falling back…if you make a mistake, then there are a bunch of people that may come and help and fix it." (Student 10)

In sum, The STEM related after-school activities helped the students develop and use their complex communication and collaboration skills (Levy & Murnane, 2004; Jerald, 2009; Wagner, 2008). The students practiced and honed their communication skills when presenting their project, listening to and talking to each other about their ideas, and when developing the shared norm that they were to respect each other's ideas and were to appreciate the diversity in their differences. Resolving any conflict and disagreement through mutual negotiation and communication further facilitated the students' development of complex communication skills, in a similar way as expressed in the statement that "skilled communicators negotiate positive outcomes with customers, subordinates, and superiors through social perceptiveness, persuasion, negotiation, instructing, and service orientation" (Peterson, Mumford, Borman, Jeanneret, & Fleishman, 1999, p. 37). Therefore, the conclusion may be reached that STEM related after school program activities inevitably contribute to developing 21st century skills, which may then assist students in solving their daily social and cultural problems as well as those revolving around political issues (NRC, 2009; Partnership for 21st Century Skills, 2011).

Conclusion

This study interpreted six STEM related after-school program activities offered at a charter school. These activities provided students the opportunity to form collaborative learning groups. The students favored the after-school program activities over their regular classroom activities because they were able to engage in open-ended activities that let them solve uncertain problems with more freedom and flexibility in groups. These activities played an important role in cultivating their interest in STEM, thus contemplating a STEM subject as their future career. The activities supporting commitment and membership to a group were a means for the students to develop and practice their communication and collaboration skills for lifelong learning.

Our conclusion is that activities reflecting collaboration, encouraging students' commitment and ownership, and building a community have the potential to help students learn from each other, develop skills, and shift their interest toward STEM fields. Such after-school program activities may be considered a means to cultivate STEM literacy because students were engaged not only in open-ended and real-world problems, but were also provided with the opportunity to acquire both problem-solving skills and experience similar to that which they might encounter in their daily lives. The community building characteristic of these STEM-related activities may further boost STEM literacy because participants are provided the means to develop a membership to a group, adopt its norms and rules in order to execute the obligations on them as determined by the group, and establish a collaborative partnership with other individuals in different communities in order to solve problems in the pursuit of a common goal. One goal can be to build a robot which allows scientists, engineers, or surgeons to collect, analyze, and interpret data in order to understand natural phenomena, while another goal can be to design, model, and establish a bridge to resolve a traffic jam problem in a metropolitan city with maximum efficiency and minimum cost.

The methodological limitations of this study include the selection of the school under investigation and the number of participants involved in the data collection process. The school in this study was chosen because of its convenience and proximity to the researchers. The school was located next to the researchers' university campus in the Southeast U.S. The university climate might have a direct effect on the teachers' and administrators' approaches to teaching and learning in the school. Therefore, the school may not be a typical representative of other U.S. schools or charter schools. Only 10 students were interviewed. We could not reach more than one girl to gain a balanced understanding of girls' views toward STEM-related activities. Therefore, we cannot claim this study to be representative of the entire population in the US. However, the findings may very well shed light on the potential characteristics of the after-school programs and their positive impact on developing students' interest in STEM subjects and students' learning trajectories.

Yet, our study findings provide indicators and indices for the potential of after-school programs activities in regard to fostering student interest in STEM fields and their learning outcomes. In this century, after school program activities may facilitate the development of competitiveness, entrepreneurialism, and collaboration skills. Through the use of these, or similar, after school programs and activities, the young generation of all countries will gain these skills so as to contribute to the efforts of their country in procuring a leader position in an ever-changing digital age. In short, we claim that designing STEM related after-school program activities along with 21st century skills is the first step in order to align schools with 21st century educational standards which will then help the young generation become lifelong learners.

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Ek/Appendix 1.

Uygulama Toplulukları Gözlem Formu (Communities of Practice Observation Form)

Kavram (Concepts)	Açıklayıcı İfadeler (Explanations)	Sorular (Questions)
Ortak Amaç (Joint Enterprise)	Uygulamanın amacı (The goal of practice) Uygulamanın gelişimi (Development of practice)	Çalışma grubunun amacı veya hedefi nedir? (What is the goal of group?) Ne gibi etkinlikler yapılmaktadır? (What kinds of activities are done in the group?)
Karşılıklı Etkileşim (Mutual Engagement)	Üyelik (Membership) Katılım (Participation) Roller (Roles) Angaje olma (Engagement)	Öğrenciler etkinliklere nasıl katılıyorlar? (How do students participate in activities?) Ne tür roller üstleniyorlar? (What kinds of roles are they engaged in?) Liderler hangi roller üstleniyor? (What are the roles of group leaders?) Tam üyelik nasıl gerçekleşiyor? (How does it occur?)
Paylaşılan Repertuar (Shared Repertoire)	Araçlar (Tools) Dil (Language) Semboller (Symbols)	Topluluğun ve grubun kullandığı/paylaştığı araçlar, semboller, ifadeler nelerdir? (What are tools/symbols/statements are used or shared by a community or a group?)

Ek/Appendix 2.

Görüşme Soruları (Interview Questions)

1. Kısaca kendinden bahseder misin?
   Please talk about yourself.
2. Hangi etkinliğe katıldın? Neden?
   Which STEM after-school clubs did you participate in? Why?
3. Katıldığın etkinlik hakkında konuşabilir misin? Neler yapıyorsun?
   Can you please talk about the STEM clubs you are participating in and tell us what your roles are in each one?
4. Sence, sınıf ortamında gördüğün etkinlikler ile katıldığın okul sonrası program etkinlikleri arasındaki benzerlikler veya farklılıklar nelerdir?
   To you, what are the similarities and differences between your regular class activities and the things you do in the STEM after-school club activities?
5. Katıldığın etkinliğin sana ne gibi katkılarda bulunduğunu düşünüyorsun?
   What types of benefits do you think you gain from the STEM after-school clubs that you participate in? Can you give examples of the benefits you obtain?
6. Katıldığın etkinliğin hangi becerileri kazanmana yardımcı olduğunu düşünüyorsun?
   By attending those STEM clubs, what types of skills do you think you develop or learn?
7. Katıldığın etkinliğin kariyer tercihi yapmanı nasıl etkilediğini düşünüyorsun?
   Do you think that participation in those STEM club activities boost your career interest towards STEM subjects?
8. Katıldığın etkinlik seni tatmin etti mi? Neden?
   Overall, how do you evaluate your experience in STEM after-school clubs?