STEM Clubs and Science Fair Competitions: Effects on Post-Secondary Matriculation

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Abstract

As the global economic competition gets tougher, American policymakers and researchers are interested in finding ways to increase the number of students pursuing STEM (Science, Technology, Engineering, and Mathematics)-related majors in order for the United States to continue its role as an economic powerhouse. A survey study was employed to investigate a multi-charter school system's (Harmony Public Schools [HPS]) after-school program in which doing a science fair project was expected for all 4th-12th grade students, and students were encouraged to participate STEM-related clubs (MATHCOUNTS, American Mathematics Competition [AMC], Science Olympiad, University Interscholastic League [UIL] and Science DEMO.). In particular, the first part of the study focused on how related matriculation of this specific school system was with the national average ($n = 230$). In the second part, the relationships between students' science fair and STEM club participation and their STEM major selection was investigated ($n = 149$). Findings showed that HPS outperformed the national average in terms of post-secondary admissions and STEM major selections. Multiple years of science fair project competition were positively related with students choosing a post-secondary STEM major ($x^2(4) = 5.32, p =. 255$). There was also a statistically significant relationship between the number of STEM clubs students participated in and their choice of STEM major ($x^2(4) = 34.22$, $p < .001$). Findings are discussed in light of developing STEM-focused after-school clubs.

Science, Technology, Engineering and Mathematics (STEM) education has become a pivotal topic for researchers in the last decade because of its vital role in the country's economic well-being. Numerous reports have emphasized the undeniable relationship between the nation's global leadership and K-12 STEM education that promotes the preparation of the next generation's scientists and innovators (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007; President's Council of Advisors on Science and Technology, 2010). However, national statistics indicate that the next generation is prepared neither for today, nor for future demands (National Research Council [NRC], 2011). For instance, international indicators (e.g., TIMMS and PISA) have shown that U.S. students did not perform well in mathematics and science putting the U.S.'s global leadership in danger (Schmidt, 2011). In addition, other studies indicated that there was a decrease in graduation rates in STEM fields (National Science Foundation [NSF], 2010). Those who were trained for STEM-related careers were not sufficient to meet the country's needs (NRC, 2011). All these data point in one direction - the economic welfare of the United States is dependent on efforts to prepare more K-12 students to enter STEM fields.

"Educate to Innovate" has been launched to boost student interest in STEM fields and cultivate STEM literacy (Obama, 2009). In this endeavor, STEM literacy, science and mathematics components of STEM education have emerged as critical to strengthening discovery and innovation as compared to the engineering and technology components (Jerald, 2009). Yet, researchers have integrated engineering topics in middle and high school curricula (Harrell, Bataineh, El-Sheikh, & Spolski, 2004; Massachusetts Science and Technology/Engineering Curriculum Framework, 2006). In addition, the education standards emphasize the interrelationships among science, mathematics, engineering and technology (NRC, 2011; Massachusetts Department of Education, 2006). Student understanding and conceptualizing of such interrelations was considered as a way to develop a positive attitude toward STEM.

Because of recent calls for action to augment the STEM workforce in a technology-driven society, different initiatives were taken to develop STEM literacy and boost individuals' interest towards STEM-related professions. The research on STEM education has focused on advanced coursework enrollment , student interest in STEM subjects and in-class experiences with STEM-related activities (Adelman, 2006; Authors, 2012; Cleaves, 2005; Munro &Elsom, 2000). With this goal in mind, public schools have integrated STEM-focused materials and activities to promote discovery and innovation (Project Lead The Way, 2011). Likewise, charter schools (a public school of choice) in the U.S. have provided low-income students with the opportunity to develop interest in STEM subjects through their after school STEM programs. Nonetheless, there is a paucity of research on STEM-related clubs offered via after school programs to supplement student classroom experiences. In addition, these supplemental programs helped students experience the scientific methods and fostered their interest towards STEM majors (Hayden, Ouyang, Scinski, Olszewski, & Bielfeldt, 2011). In this study, we aim to investigate the relationships between science fair and STEM club participation and STEM major selection at a multi-campus charter school system.

Theoretical Framework

After School Programs and Science Fairs

After school programs have gained prominence in education communities because of their potential to promote student learning and develop scientific literacy (Robelen, 2011). A 14-member committee focused on Learning Science in Informal Environments examined the qualities of learning experiences in informal settings. This committee noted that informal learning environments or out of school settings were a great opportunity to support science learning, develop competence and enhance student achievement. The committee stated:

> Programs for science learning take place in schools and community-based and science-rich organizations and include sustained, self-organized activities of science enthusiasts. There is mounting evidence that structured, non-school science programs can feed or stimulate the science-specific interests of adults and children, may positively influence academic achievement for students, and may expand participants' sense of future science career options (NRC, 2009, pp. 2-3).

The phrase informal learning environment is an umbrella term that covers museums and zoos as well as community and after school programs. The focus for this article was after school programs. After school programs are becoming an indispensible part of the school (Worrell & Bucknavage, 2004). As long as the aims and content of activities in after school programs are well defined, they are a means to "foster interpersonal competence, help define life goals, and promote educational success" (Wirt, 2011, p. 48). Through these after school programs, students learn how to work and communicate with their peers and teachers differently from their interaction in their regular classrooms (Mahoney, Cairns, & Farmer, 2003).

The Afterschool Alliance, the National Afterschool Association, and the National Summer Learning Association deemed 2011 as the "Year of Science in After-School" (Afterschool Alliance, 2011). One of the objectives was to build sustainable after school programs. Likewise, some initiatives in California and Missouri established statewide systems promoting high quality after school programs. These initiatives emphasized creating quality curricular materials for after school programs in STEM fields and suggested training after school program staff, and reviewing and revising the activities. However, the greatest threat to after school programs was the lack of institutionalization and sustainability (American Association of School Administrators, (n.d.); Robelen, 2011).

After school program activities were a means for students to better understand scientific concepts, processes and procedure (McGee-Brown, Martin, Monsaas, & Stombler, 2003). These activities enhance student achievement and interest in science and allowed students to gain scientific inquiry skills and develop scientific reasoning as well as to improve their communication skills (Abernathy & Vineyard, 2001; Bernard, 2005; Czerniak &Lumpe, 1996; Grote, 1995a). These activities motivated students to work together and share ideas, experience and knowledge. In turn, students took ownership of their ideas and learning, and felt a sense of belonging to a group (Abernathy & Vineyard, 2001). Students who viewed themselves as members of a scientific learning community were more motivated to participate and commit themselves in the activities.

After school program activities integrate students' intellectual side and combine with a sense of membership to a group. Therefore, these activities were an avenue for developing communities of practice (Wenger, 1998). Overall, after school programs stimulated students' interests and may positively influence academic achievement of them, as well as expand participants' sense of future science career options (NRC, 2009).

Interest in STEM-Related Fields

Interest in STEM can be described as one's positive inclination toward science, technology, engineering and mathematics [STEM] fields. When students develop an interest in one of those content areas of these subjects and related activities, this interest may lead them to pursue a STEM-related career (Buxton, 2001). For instance, research claims that students' engagement in authentic informal educational activities in their early years enhances their interest in STEM (Maltese & Tai, 2010; Tindall & Hamil, 2004). Also, studies indicated that activities set in the real world and incorporate students' daily lives increase their interest in STEM as well (Cleaves, 2005; Lindahl, 2007). Therefore, offering a supplementary after school program along with regular school work may help students consider STEM majors in college (Bell, Lewenstein, Shouse, & Feder, 2009; NRC, 2009; Zoldosova & Prokop, 2006).

The above findings can be explained with Carl Rogers' facilitative learning and Albert Bandura's social learning theory. The basic premise of facilitative learning theory is that learning occurs when the educator acts as a facilitator and establishes an atmosphere in which students feel comfortable to explore and test new ideas without having the fear of external threats (Laird, 1985). Indeed, teacher's roles in after school clubs is no more than facilitator as well as setting the stage for a safe and productive collaborative project study groups. In these small groups, students are encouraged to take responsibility for their own learning and development of the project that they are going to compete with. Most of the input and research comes from students in completing the task with the feedback from their teachers. Bandura's social learning theory explains the rest of what happens in those study groups. As students research and see how other projects are done or how their teacher/facilitator and/or coach demonstrates sample steps of what is being studied, students learn and start imitating, observational learning, thus developing their own learning. Bandura also indicated that external and environmental factors are not the only factors affecting learning and behavior. He further mentioned intrinsic reinforcement as a form of internal motivation, such as satisfaction, pride and sense of accomplishment (1977). As students become acquainted with the content they work with and become successful at competitions, they start feeling the pride of being part of the club, thus considering future competitions in similar fields. Eventually, this may lead students to consider studying those subjects in college as well while most high school students do not have any idea what career they are going to pursue in college (Hansen, 2011).

The purpose of this study was to investigate one charter school system in terms of their matriculation data and the relationship between students' participation in science fair competitions and supplemental STEM clubs and their post secondary STEM major selection. Specifically, we investigated how students from a charter school system matriculate into postsecondary education and the influence that school clubs and science fairs have on this matriculation:

1. How does this charter school compare to the national average for STEM major matriculation?

2. What is the relationship between students' STEM after school clubs and science fair participation and their college STEM major choice?

Method

Research Setting

Charter Schools. Charter schools are an alternative to public schools and 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). They are funded by a state, but run independently so they can hire their own teachers and staff, and manage their own budget. According to the TEA (2009), open-enrollment charter schools receive state funds based on the average daily attendance of students, just like other school districts.

System versus Multiple Stand-alone Charters. We specifically focused on one charter school system because of their broad menu of after school clubs and required science fair participation. This allowed for a greater sample size and diversity in sample characteristics while holding core educational mission and vision constant. Some of the campuses were designated STEM Academies. The Harmony Public Schools (HPS) differs from other charter schools because it is a system of charters located across Texas and this affords certain benefits of scale but also logistical challenges.

Harmony Public Schools (HPS) is a charter school system consisting of 36 schools serving more than 20,000 students, each campus with their own building level administration. Harmony students were female (51 percent), Hispanic (47 percent), and low SES (56 percent free or reduced cost lunch). HPS was operated by the Houston-based nonprofit organization Cosmos Foundation. The focus of HPS was on mathematics, science, engineering and computer technologies. Students attending HPS were encouraged to choose after school programs relevant to STEM subjects.

After school programs at HPS

HPS students participated in seven STEM-related after school program activities. These ranged from Robotics, MATHCOUNTS, American Mathematics Competition (AMC), Science Olympiad, Science Fair, Science EXPO and Univer-

Student Demographics of Seniors by Percentages for Research Questions 1 and 2

	Male	Female	Hispanic	Black	White	Asian	Econ Disadvantaged
RQ1[1]	49	51	49	14	22	13	67
RQ2[2]	48	52	52	6	21	17	65

Note. 1 is for years 2007-2011; 2 is for only 2011.

Table 1

sity Interscholastic League (UIL).

Robotics activities included designing, programming and problem solving activities through ready-made computer software. For example, students worked in collaboration to build, design and test their model. They presented their design to audiences during competitions. MATHCOUNTS activities were designed to increase student achievement in mathematics as well as to allow students to realize the connection between mathematics and their daily life including their parents, school and society. During MATHCOUNTS activities, group members practice basic problem-solving strategies (e.g., identifying the problem, devising a plan and decision making for the possible options) to develop problem-solving skills. American Mathematics Competition was used to increase student interest in mathematics and help them gain problem-solving skills. AMC activities included a comprehensive presentation of traditional and non-traditional problem solving techniques, including plane and transformational geometries, coloring proof and number theory.

Science fairs at HPS. Science fairs were organized at the four different levels: school level, regional level, state level and international level. Science Olympiad went beyond science fairs and was organized in individual schools. Students were expected to participate in specific projects determined by the Science Olympiad guidelines. Winners of competitions were expected to participate in subsequent Statewide Olympiads held on a university campus. Student groups presented their projects to a group of judges. The judges included faculty, researchers and graduate students. The University Interscholastic League [UIL] offered challenging and rigorous academic contests in various subjects in elementary, middle and high school categories, including calculator and computer applications, mathematics, number sense and science. Science DEMO is a type of demonstration of a science topic. The purpose of science DEMO is to engage students with a science topic that has a real-life application in science classrooms. Students are given the opportunity to demonstrate their science DEMO show at Science Expos.

Participants

The first question dealt with matriculation and the sample included seniors (n = 230) from a Texas-based charter school system. Out of 36 campuses, a total of eight Harmony schools had graduating seniors between the 2007-2011 school years. The second question dealt with science fair and club participation data and their influence on students' STEM major selection. The sample consisted of high school seniors of the same charter school system after 2010 (n = 149) because records were not retained before 2010. Table 1 summarizes

	Overall	Male	Female	Black	Hispanics	White	Econ Disadvantaged
4-year Matriculation	88	91	85	88	87	88	87
2-Year Matriculation	12	9	15	12	13	12	13
STEM Matriculation	65	49	51	94	57	68	87
National average for STEM Matriculation[1]	33	29	15	18	22	33	Not Available

Note: 1 is taken from National Center for Education Statistics. (2009, July).

Table 2

the demographics for both research questions.

Instrument

The purpose of this study was to investigate how Harmony schools and the national average for STEM major matriculation differed as well as how Harmony students' science fair and after school STEM club participation affected their major selection. The researchers developed an online survey to satisfy this purpose, which included questions about participant demographics (gender, ethnicity and lunch status), college acceptance status (4-year or 2-year or no college enrollment), majors they selected, years of their science fair participation, and types of after school STEM club participation (see Appendix).

Chi-Square Test Results for STEM Major Choice by # of STEM Clubs and # of Years in Science Fair Competitions

		STEM Major Choice[1] 0	1	2	Total	x^2
# of Years in	1	2	3	5	10	
Science Fair	2	14	28	11	53	
Competitions	3	29	38	19	86	$x^2(4)=5.32$, $p>.05$.
Total		45	69	35	149	
# of STEM	1	29	27	32	88	
Clubs	2	14	21	2	37	
	3	2	21	1	24	$x^2(4)=34.22$, $p<.05$.
Total		45	69	35	149	

Note: [1] stands for: 0 non-STEM major, 1 STEM major, 2 general education

Table 3

Data Collection and Analyses

After receiving administrative permission, eight high school counselors were contacted by phone and provided information about the study and online survey to fill out their corresponding school's matriculation data within a month.

First, data on student majors were categorized as STEM (1), non-STEM (0) and general (2) majors according to the U.S. Immigration and Customs Enforcement's STEM-designated degree program list (2011) including 328 STEM majors in total. Second, data were analyzed using SPSS 20.0.0 software. In order to seek an answer to the first question, descriptive statistics were computed to identify matriculation rates by students, majors and demographics. Because the dependent variable was not continuous, non-parametric two-way chi-square statistics and cross tab analysis were used to answer the second question in which the relationships between the number of years in science fair participation, number of STEM clubs they participated, and students' STEM major choices in colleges, were investigated.

Results

To answer the first research question, whether HPS matriculation data were different from national trends was investigated. In all areas, HPS outperformed the national average in terms of post-secondary admissions and STEM major selections (see Table 2).

It was found that all HSP's seniors graduated (100 percent) from their respective high schools and gained admission to post-secondary institutions, whereas the national and Texas state high school graduation rates were 72 percent and 67.8 percent, respectively (Education Week, 2011). While HPS had 88 percent 4-year college admission rate, the national average was 62.3 percent as of Fall 2007 (National Center for Education Statistics, 2009). Males (91 percent), females (85 percent), Hispanics (87 percent), African Americans (88 percent), Whites (88 percent), and economically disadvantaged (87 percent) gained admission to 4-year colleges and universities (see Table 1). Among those, 49 percent of males, 51 percent of females, 57 percent of Hispanics, 94 percent of African Americans, 68 percent of Whites, and 87 percent of economically disadvantaged students reported that they selected STEM majors when enrolling in post secondary institutions (see Table 2). HPS STEM matriculation percentages were higher than the national comparison in STEM matriculation data in all groups as well.

The second question addressed how students' science fair and STEM club participation was related to career selections when they enrolled in colleges. Even though there was no statistically significant difference ($x^2(4)=5.32$, $p=.255$), there was still a pattern (see Table 3) demonstrating that those who chose STEM majors competed in more years of science fairs (3 or more years). Because each and every student in grades 4-12 in HSP have a requirement to enter the annual science fairs, thus it follows that the longer the students stayed enrolled in HSP, there was more likelihood that those students would pursue STEM majors in colleges and universities.

Additionally, there was a statistically significant relationship ($x^2(4)=34.22$, $p<.001$) between the number of STEM clubs a student participated in and their STEM major selection (see Table 3). It was clear that as a student's number of STEM club participation increased, they choose more STEM majors in college. Thus, students who were naturally interested in STEM subjects and were provided an environment where there were options of STEM clubs, competitions and fairs, chose STEM majors at a higher percentage than the national average.

Discussion

Students who attended STEM after school clubs had a higher percentage of post-secondary matriculation in STEM majors than the national average. This participation in clubs seems to provide an area of interest for students who may already be inclined toward a STEM field. However, many in the STEM pipeline dropout so this plethora of club opportunities may provide the impetus for students to remain in STEM. Some possible reasons could include that they see the applicability of the content they are learning in school, they are able to channel self-interest in a club into intrinsic motivation in the classroom to more fully participate in their club choices, or they may simply have a more creative environment with fewer restrictions on their learning and they persist in their STEM interests. A potential study would be to trace whether these students stay in the STEM pipeline and graduate as a STEM professional and there is a relationship between those who participated in one of STEM clubs in high school and graduate as a STEM professional. A more fine-grained study will need to unpack the actual causes for retaining these students in STEM.

Another important finding of this study was that engaging students with STEM-related clubs in early years of their secondary education cultivates STEM interest in students, thus considering STEM fields as a profession. This is consistent with the current research (Maltese & Tai, 2010; Sullivan, 2007; Tindall & Hamil, 2004) saying that students with positive experiences in their early grades with science and the STEM subjects were more likely to choose a STEM-related field as a career. On the other hand, the data did not include whether students who participated in science fair or other club competitions got any reward in the end. This would be a future study to investigate whether students' failure or success at competitions affected their major selections.

One implication from this study would be to encourage school districts to develop a variety of optional, flexible, free, fun and competitively oriented extra-curricular after-school programs so they can facilitate students in developing positive attitudes towards STEM fields.

Conclusions

While policy makers and researchers are interested in finding ways to increase the number of students pursuing STEM-related majors, they have to consider looking at successful models that produce more students who prefer pursuing STEM majors in colleges and universities. Our findings support the idea of offering a variety of after school STEM clubs and requiring students to complete science fair projects as part of their regular school curriculum. Although it is much more difficult to generalize our findings from a multi-school charter system, large-scale efforts to understand these issues are critical to recognize how students in after-school clubs choose to study STEM subjects during their post-secondary years.

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Appendix

Survey

1. Gender
2. Ethnicity
3. Lunch Status (Free, Reduced, or Paid)
4. 4-year college (Yes or No)
5. 2-year college (Yes or No)
6. Major selected at colleges
7. STEM major (Yes or No)
8. STEM after school club participation (Yes or No)
9. Name of the STEM after school clubs
10. Years of science fair participation

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