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Abstract

It is well known that strong extracurricular STEM programs provide multiple arenas for students to expand on classroom curriculum, complementing STEM skills with creative thinking and open-ended problem solving. It has been shown that there is a relationship between the number of STEM clubs students participated in and their choice of STEM major (Sahin, 2013). Considering financial problems, including budget cuts, it gets really challenging for schools to provide a plethora of clubs. For this reason, it would be very beneficial for K–12 schools to know if certain clubs are more effective in changing attitudes toward STEM majors, and therefore help strengthen the pipeline for STEM careers.

A quantitative study was designed to investigate if any specific STEM club amongst the ones offered at the Sonoran Schools (SS), a charter school system, created a significant difference in students' perception toward STEM fields and majors. The data were collected through an online survey of 1,167 students across six charter schools, serving grades K–12 under the same charter system, at the end of the 2015 school year. Students who were not enrolled in STEM-related extracurricular activities were considered as a baseline. The data have shown that extracurricular STEM club involvement has significantly impacted the attitude toward STEM perception. The analysis of the data also showed that it is possible to close the notorious gender and ethnicity gaps in STEM perception and provide a diverse student population to the STEM pipeline. The hypothesis that "there is a range of impact from clubs, and some are more impactful than others" has been disproved to show that there is no significant difference between the clubs when it comes to their impact on student STEM perception. The findings of this study are expected to help K–12 stakeholders, administrators, club organizers, and mentors to use their resources effectively.

Keywords

STEM attitude, STEM perception, extracurricular clubs, STEM gap, STEM pipeline

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How to Shape Attitudes Toward STEM Careers: The Search for the Most Impactful Extracurricular Clubs

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Abstract

It is well known that strong extracurricular STEM programs provide multiple arenas for students to expand on classroom curriculum, complementing STEM skills with creative thinking and open-ended problem solving. It has been shown that there is a relationship between the number of STEM clubs students participated in and their choice of STEM major (Sahin, 2013). Considering financial problems, including budget cuts, it gets really challenging for schools to provide a plethora of clubs. For this reason, it would be very beneficial for K–12 schools to know if certain clubs are more effective in changing attitudes toward STEM majors, and therefore help strengthen the pipeline for STEM careers.

A quantitative study was designed to investigate if any specific STEM club amongst the ones offered at the Sonoran Schools (SS), a charter school system, created a significant difference in students' perception toward STEM fields and majors. The data were collected through an online survey of 1,167 students across six charter schools, serving grades K–12 under the same charter system, at the end of the 2015 school year. Students who were not enrolled in STEM-related extracurricular activities were considered as a baseline. The data have shown that extracurricular STEM club involvement has significantly impacted the attitude toward STEM perception. The analysis of the data also showed that it is possible to close the notorious gender and ethnicity gaps in STEM perception and provide a diverse student population to the STEM pipeline. The hypothesis that "there is a range of impact from clubs, and some are more impactful than others" has been disproved to show that there is no significant difference between the clubs when it comes to their impact on student STEM perception. The findings of this study are expected to help K–12 stakeholders, administrators, club organizers, and mentors to use their resources effectively.

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Literature Review

The increasing need for professionals in STEM fields has been expressed at the national and state levels. On the national level, the President's Council of Advisors on Science and Technology (2010) documented "troubling signs" for the nation's future STEM workforce. The U.S. Bureau of Labor Statistics projects that, during the period of 2012–2022, employment in science and engineering occupations will grow by 14.8%, compared to 10.8% for all occupations (NSF, 2016). The Council has predicted that over the next decade 1 million additional STEM graduates will be needed. Warning signs that show increasing demand for STEM professionals will not be met include diminished standings in international comparisons of our students' performance in science and mathematics, as well as the large interest and achievement gaps among underrepresented groups in STEM. National Assessment of Educational Progress (NAEP) results show that "compared with 43 percent of White students and 61 percent of Asian students, just 13 percent and 19 percent of Black and Hispanic students, respectively, are scoring at or above proficiency in eighth-grade mathematics" (Tanenbaum, 2016). The President's Council specifically noted that the problem is "not just a lack of proficiency among American students;there is also a lack of interest in STEM fields among many students" (p. vi). From 2011 to 2015, the percentage of students interested in STEM increased by 1% to reach 49%, according to the national STEM study performed by Attainment of College and Career Readiness (ACT, 2015).

Similar concerns have been recognized at the state level in numerous states. For instance, it is estimated that the State of Arizona will have 166,000 STEM and STEM-related jobs to fill by 2018 (AZ Board of Regents). In 2013, a substantial number of STEM-related jobs in North Carolina businesses went unfilled due to the shortage of qualified candidates (Porter, 2015). There are an estimated 400,000 STEM-related jobs in North Carolina with more than 70,000 net creations of new positions projected by 2020 (NC Department of Public Instruction, 2013, p. 4). The increasing STEM worker shortage is well documented.

On the contrary, Charette (2013) suggested that there are more STEM workers than suitable jobs and many STEM graduates work in non-STEM related jobs. Whether one thinks there is a STEM shortage or surplus, an important factor that hinders any STEM graduate from securing a STEM job is an inadequate level of academic preparation for college. This preparation begins in grades K–12.

STEM integration in K–12 has been on the rise since the idea was introduced almost a decade ago (Nathan & Pearson, 2014). Zuger (2012) noted that the most commonly reported challenges that K–12 schools face in implementing STEM programs are funding (48.4%), inadequate K–8 education (46.5%), insufficient teacher PD (46.4%), unclear best practices for STEM education (35.3%), and lack of qualified teachers (33.2%). Teacher preparation programs have been slow to train and prepare teachers to effectively teach at high-STEM-competency-required schools, causing schools to look for this expertise in the professional arena. This idea was also supported by the Obama administration's "Educate to Innovate" program. Schools reached out to stakeholders, local businesses, and communities in their pursuit of STEM-centered educational experiences, and established a plethora of after-school club opportunities depending on their resources.

In order to close the curriculum gap in grades K–8, there have been numerous initiatives such as STEM Pathways, Common Core State Standards, Next Generation Science Standards, Race to the Top, and the addition of 100,000 New STEM educators, and so forth (Porter, 2015). Materials for student learning and engagement in STEM fields have been developed through private and government channels such as Project Lead the Way, Engineering is Elementary, Engineering by Design, Probase, and others to support teachers with the necessary understanding and skills to teach engineering (Mativo & Park, 2012). In addition, several charter or magnet schools are formed with rigorous, college-ready, STEM-focused curriculum while also preparing pupils for higher-level study and professional futures in STEM (Thomasian, 2011). Students at these schools are generally involved with hands-on projects in an informal teaching environment, and interact with practicing engineers, inventors, and scientists through extracurricular experiences (VanMeter-Adams et al., 2014; Thomasian, 2011). Research has shown that "know an engineer" is more frequently reported by students who remained in engineering than those who switched out of the program (Honken & Ralston, 2013). The extracurricular programs/clubs were expected to provide students, especially underrepresented minorities (females, blacks, and Hispanics), with the opportunity to learn about STEM-related fields through hands-on and teamwork experiences (Porter, 2015; Alvarez & Edwards, 2010).

As the STEM-2026 Vision states, "recognition is growing among educators that learning occurs everywhere from the formal classroom to informal settings such as makerspaces, libraries, and museums to more structured out-of-school contexts such as extracurricular programs" (Tanenbaum, 2016, p. 21). Students participating in extracurricular STEM activities have shown to be more likely to develop the confidence and interest to major in post-secondary STEM disciplines as a result of their exposure, increased awareness, and richer experience (Alvarez & Edwards, 2010; Sahin, 2013; Koehler et al., 2013; VanMeter-Adams et al., 2014). It has also been shown that there is a significant relationship between the number of clubs in which students participated and their choice of STEM major (Sahin 2013).

Theoretical Framework

The Sonoran Schools (SS) system, with the motto "STEM Education College Preparation," provides K–12 STEM education in a small-school environment at three schools in the Phoenix metropolitan area and three schools in the Tucson area. Since they were established in 1999, the SS has emphasized hands-on learning and individual and team exploration to support all learners' unique needs and provide STEM education. From kindergarten through 12th grade, the students take computer science courses and master computer programming skills. All students are also required to complete a STEM demo project, and present it to their class and school community. The curriculum providers include STEMscopes and Engineering is Elementary at the elementary level, Project Lead the Way and Project-Based Inquiry Science at the middle school level, and Active Science at the high school level. The College Board's AP curriculum is utilized for the high school AP science courses in collaboration with our dual enrollment partners.

The SS also provides a strong extracurricular program to offer multiple arenas for students to expand on classroom curriculum, complementing STEM skills with creative thinking and open-ended problem solving. The types of extracurricular activities offered at the SS include but are not limited to the following competitive clubs: First Lego League Jr., First Lego League, First Tech Challenge, First Robotics Competition, Odyssey of the Mind, KIDstruction, Underwater Robotics, Science Olympiad, Math Counts, Future City, Science Bowl, Science Olympiad, and A+ Math.

The fact remains that funding and availability of resources, especially in socioeconomically disadvantaged areas, continue to be inconsistent. The 2012 National Survey on STEM Education of 1,079 educators suggests that, similar to the results from the 2010 and 2011 national surveys, inadequate funding continues to be the leading challenge for schools to implement any program (Zuger, 2012).

This paper summarizes the findings from a 2015 end-of-year survey study on the ability of 1,167 students from six charter schools to answer the following research questions:

RQ1: Is there any significant STEM perception difference amongst students who are enrolled in a STEM club versus no-club students?

RQ2: Does gender play a role in STEM perception?

RQ3: Does any specific club provide a significant difference in STEM perception when compared to any other club?

RQ4: Is there any significant STEM perception difference between different ethnic groups depending on their club enrollment status?

Data Collection and Manipulation

The team received approval from the Northern Arizona University Institutional Review Board (#838379-1) to analyze the data compiled from surveying 1,167 students enrolled in six charter schools. These schools, serving different ranges of K–12, are located in and southwest of Phoenix. The survey data were analyzed to determine if there was any change in students' attitude toward STEM fields while taking their ethnicity, gender, and STEM club enrollment into consideration. The Overall Perception of STEM (Overall_Per_STEM) construct was created by summarizing 26 survey questions measuring perceptions and likeliness of engineering, science, and math classes by weighing each of these subjects equally (see Appendix A). The variable Overall Perception of STEM (Overall_Per_STEM) was calculated by taking the arithmetic mean of three sub parameters: Overall Perception of Math, Overall Perception of Science, and Overall Perception of Engineering (Appendix A: Construct a, b, and c respectively). These variables were calculated by taking the simple, equally weighted means of Likert-scaled questions in a survey data set. For each variable, related survey questions and descriptive statistics are given in Appendix A. The students who were enrolled in a STEM club are labeled as their club name abbreviation (Table 1), and students who were not enrolled in any STEM club are labeled as Null.

The survey asked an open-ended question regarding ethnicity, and the 35 different answers received were clumped and summarized into six total ethnicity categories.

Table 1
Gender distribution across STEM clubs and ethnic groups.

Abbreviation	STEM Clubs	Female	Male	Unknown	Total
AM	A+Math/Mathcounts	18	42	3	63
FC	Future City	1	4	2	7
FLL	FIRST Lego League	15	39	1	55
FTC	FIRST Tech Challenge	12	21		33
KI	Kidstruction	5	5	2	12
MS	Mad Science	8	7	1	16
OM	Odyssey of the Mind	11	14		25
SB	Science Bowl/A+Science/A-STEM Clubs	13	12	1	26
SC	Science Club	14	10	2	26
SO	Science Olympiad	68	58	2	128
UWR	Underwater Robotics - SeaPerch	3	2	1	6
Null	Null	299	316	155	770
Total		467	530	170	1167
Abbreviation	**Ethnicity**	**Female**	**Male**	**Unknown**	**Total**
AS	Asian	84	74	2	160
BA	Black or African American	62	55	2	119
HL	Hispanic or Latino	60	62	4	126
MX	Two or more races	59	78	3	140
RA	Refused to answer	60	76	156	292
WH	White	142	185	3	330
Total		467	530	170	1167

Some students provided meaningless responses or refused to answer; these were combined in the category "refused to answer." Table 1 summarizes the ethnicity and gender distribution of students for different STEM clubs.

In this study, IBM SPSS version 20 (IBM SPSS, 2011) is used to perform the independent samples *t*-test. As known, different hypothesis tests could be used in different situations. For example, *t*-test and Analysis of Variance (ANOVA) are two parametric statistical techniques used to test a hypothesis. But there is a thin line of demarcation amidst *t*-test and ANOVA. In practical applications, when the population means of only two groups are to be compared, the *t*-test is used (Fisher Box, 1987), but when means of more than two groups are to be compared, ANOVA is used. Since the dual comparisons of the groups are taken into consideration in this study, *t*-tests are preferred. The relationship between variables were compared against $p < 0.05$, to yield 95% confidence limit.

Results and Discussion

Data were analyzed to see if enrollment in any STEM club changes students' perception toward STEM fields, namely mathematics, science, and engineering. The total number of students who were enrolled in a STEM club was 372, with a mean STEM perception value of 3.9 ± 0.595. No- club students totaled 565, with a mean STEM perception value of 3.511 ± 0.699. Table 2 shows independent samples *t*-test results when students' STEM perceptions were compared depending on their club enrollment status.

As shown in Table 2, STEM club enrollment has a statistically significant correlation with STEM perception ($p < 0.05$). Students who are enrolled in a STEM club have a higher mean perception value as compared to students who are not enrolled in any STEM Club. This result is aligned with the literature (Alvarez & Edwards, 2010; Sahin, 2013; Koehler et al., 2013; VanMeter-Adams et al., 2014).

When STEM perception was analyzed according to gender for RQ2, it was revealed that gender didn't have a significant correlation with STEM perception, neither among students who are enrolled in a STEM club, nor among students who are not enrolled in any STEM club. All significance values were greater than 0.05 (Table 3). This is in contrast to Stoeger et al.'s findings that STEM interest is almost three times higher for boys than for girls. The study also concluded that girls, although not limited in their ability, need positive mentor or instructor support to overcome ingrained stereotypes (Stoeger et al., 2013). The gender gap in this study may have been closed due to the STEM-focused school culture and various kinds of activities at school, in addition to the STEM extracurricular clubs.

To be able to answer RQ3, we analyzed if any of the clubs would create a significant difference on students' STEM perception when compared to any other club offered. Clubs that enrolled fewer than 25 students were eliminated from this analysis. Table 4 summarizes the impact of enrollment in individual STEM clubs on students' STEM perception, and compares that to the impact of any other specific club, and to the baseline composed of students not enrolled in any STEM club.

As shown in Table 4, there is a significant difference among STEM perceptions when students who are not enrolled in any club are compared to the students who are enrolled in the Science Olympiad (SO) club ($p < 0.05$). Students enrolled in SO showed significantly higher STEM perception than students who are not enrolled in any STEM club. No other club enrollment created a noticeable or significantly higher change on STEM perception over any other club or null. All possible club combinations were compared to each other by creating a 9 x 9 matrix and resulted in non-significant correlations (see Table 4).

Science Olympiad (SO) club students ($N = 121$) had a mean STEM perception of 3.931 ± 0.553, as compared to Null students ($N = 565$), who had a mean STEM perception of 3.511 ± 0.699. The independent *t*-test significance test result is shown in Table 5.

Science Olympiad club was expected to be very similar in nature to the other competitive STEM clubs analyzed in this work. Interviews with the SO coaches at two schools revealed that Science Olympiad team students work on 23 different topics, ranging from biology to robotics, for the

Table 3
The impact of gender on STEM perception based on STEM club enrollment.

$p < 0.05$	Gender		Sig.
Club Only	F	M	0.53
Non Club	F	M	0.767
All Data	F	M	0.862

Table 2
The results of an independent samples test for overall STEM perception among students enrolled in a STEM club versus no club enrollment.

		Levene's Test for Equality of Variances		*t*-test for Equality of Means		
		F	Sig.	*t*	*Df*	Sig. (2-tailed)
Overall_Per_STEM	Equal variances assumed	8.644	.003	8.911	935	.000
	Equal variances not assumed			9.212	876.358	.000

Table 4
Significance values of STEM perception comparisons between specific STEM clubs and null.

	AM	FLL	FTC	KI	MS	OM	SB	SC	SO	NULL
AM	-									
FLL	0.203	-								
FTC	0.179	0.812	-							
KI	0.25	0.668	0.782	-						
MS	0.226	0.707	0.845	0.916	-					
OM	0.604	0.701	0.601	0.574	0.577	-				
SB	0.500	0.732	0.589	0.498	0.516	0.944	-			
SC	0.126	0.574	0.731	0.999	0.907	0.466	0.408	-		
SO	0.098	0.996	0.778	0.628	0.669	0.630	0.681	0.512	-	
NULL	0.87	0.096	0.118	0.231	0.200	0.485	0.413	0.093	*0.013**	-

*statistically significant

Table 5
The independent *t*-test results for comparison of mean STEM perception for Science Olympiad Club students versus null.

		Levene's Test for Equality of Variances		*t*-test for Equality of Means		
		F	**Sig.**	***t***	***Df***	**Sig. (2-tailed)**
Overall_Per_STEM	Equal variances assumed	6.169	.013	6.204	684	.000
	Equal variances not assumed			7.213	211.055	.000

Table 6
The significance values of *t*-tests for STEM perception difference among different ethnic groups, further broken down to club only (CO) and no club (NC) students.

	HL			WH			AS			MX			RA			BA		
	ALL	**CO**	**NC**	**ALL**	**CO**	**NC**	**ALL**	**CO**	**NC**	**ALL**	**CO**	**NC**	**ALL**	**CO**	**NC**	**ALL**	**CO**	**NC**
HL	-	-	-															
WH	0.347	0.393	0.937	-	-	-												
AS	***0.007****	0.768	0.064	0.065	0.434	0.072	-	-	-									
MX	0.459	0.261	0.593	0.068	0.423	0.492	***0.001****	0.202	***0.023****	-	-	-						
RA	0.716	0.655	0.498	0.583	0.722	0.371	***0.036****	0.771	***0.018****	0.274	0.389	0.891	-	-	-			
BA	0.669	0.942	0.779	0.63	0.396	0.701	***0.036****	0.823	***0.029****	0.275	0.243	0.789	0.982	0.679	0.683	-	-	-

*statistically significant

course of a year. Each student needs to compete in two to three different topics, which might help students to be exposed to deeper STEM concepts and play a role on their overall perception. The club meets three to four times per week after school, and they often do team-building activities together (e.g., movie nights and sleep overs).

The last research question (RQ4) this study looked at was ethnicity related. When overall STEM perception was analyzed for different ethnic groups in the entire sample, Asian students showed statistically-significant higher STEM perception than any other ethnic group. Results are summarized in Table 6. The analysis was done in three subgroups: club only (CO), no club (NC), and all data (ALL).

The importance of attracting a more diverse student body toward STEM fields has been well noted in the literature. Historically, Asian students have shown higher achievement and interest toward STEM (Tanenbaum, 2016; Cohoon et al., 2011). Our findings are aligned with these results; Asian students had a p value less than 0.05 when their STEM perception was compared to HL (Hispanic and Latino), MX (two or more races), RA (refused to answer), and BA (African American, Black) for all students not enrolled in a club. It is important to notice, though, that when Asian students were compared with those previously mentioned groups amongst club-enrolled students, the significance of the STEM perception disappears. This might suggest that STEM club enrollment status aligns the perceptions of students regardless of their ethnicity.

Conclusion

This study has analyzed 2015 survey data of 1,167 charter school students (K–12) from metropolitan Phoenix, AZ. The analysis indicated that there is a significant STEM perception difference between students who are enrolled in a STEM Club, versus students who are not enrolled in any club. However, when clubs are individually analyzed to see if any club created a significant difference in STEM perception when compared to other clubs, the results showed that there is no significant difference among clubs. This might suggest that the specific nature of the club is not necessarily important for students' perception change, but it is important for students to be involved in any kind of competitive STEM club.

The perception of STEM didn't change significantly when gender was considered for our sample. Female students had similar perceptions to their male counterparts. This is interesting to note, since the literature showed significantly lower perception of STEM by girls (Stoeger et al., 2013). This might be because the schools sampled in this study are STEM-oriented to start with, and students are exposed to STEM on a regular basis, not just during extracurricular club activities.

When different ethnic groups were compared, it was found that our sample was in agreement with the literature. Asian students showed significant difference in their STEM perception when compared to other ethnic groups, namely Hispanic, mixed, and African American; however, this significance disappeared among club students. This might be due to the nature of the STEM clubs, as all students who are enrolled in any STEM club seem to show more similar STEM perceptions despite their ethnic backgrounds.

The premise is that science, technology, engineering, and mathematics (STEM) exposure through extracurricular clubs has an effect on minority students' perception of STEM-related careers.

Limitations and Future Work

It is known that all data-based studies are constrained with the quality and quantity of data and research, and the results could only be generalizable beyond the specific conditions of the research (Pektas, 2013). The results presented here are limited to the data gathered from this specific charter management system, the Sonoran Schools. Additionally, some charter schools emphasize STEM more than others, and are considered magnet schools for some. This study's results should also be evaluated by keeping the 2016 Condition of Education Report in mind: "between school years 2003–2004 and 2013–2014, overall public charter school enrollment has increased from 0.8 million to 2.5 million. During this period, the percentage of public school students who attended charter schools increased from 1.6 to 5.1 percent" (National Center for Education Statistics, 2016). With charter schools' growing enrollment and STEM emphasis, the results of this study might be generalized with more confidence.

This study has also focused on after-school clubs and their impact on students. There were no exclusively technology-oriented clubs in the schools we studied; however, they all depended on technology and exposed students to technology in STEM. Although technology is not analyzed as a construct separately, authors believe that items c2, c3, c4 and c6, and c8 under "Engineering" are directly related with technology and measure skills for technology (see Appendix A).

Future work in this area could compare this specific charter school to other charter school systems, or to a traditional district school, to evaluate the kinds of correlations and similarities that would arise.

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Appendix A

	Questions
	Overall Perception MATH (Construct a)
a1	Math has been my worst subject.
a2	I would consider choosing a career that uses math.
a3	Math is hard for me.
a4	I am the type of student who does well in math.
a5	I can handle most subjects well, but I cannot do a good job with math.
a6	I am sure I could do advanced work in math.
a7	I can get good grades in math.
a8	I am good at math.
	Overall Perception SCIENCE (Construct b)
b1	I am sure of myself when I do science.
b2	I would consider a career in science.
b3	I expect to use science when I get out of school.
b4	Knowing science will help me earn a living.
b5	I will need science for my future work.
b6	I know I can do well in science.
b7	Science will be important to me in my life's work.
b8	I can handle most subjects well, but I cannot do a good job with science.
b9	I am sure I could do advanced work in science.
	Overall Perception ENGINEERING (Construct c)
c1	I like to imagine creating new products.
c2	If I learn engineering, then I can improve things that people use every day.
c3	I am good at building and fixing things.
c4	I am interested in what makes machines work.
c5	Designing products or structures will be important for my future work.
c6	I am curious about how electronics work.
c7	I would like to use creativity and innovation in my future work.
c8	Knowing how to use math and science together will allow me to invent useful things.
c9	I believe I can be successful in a career in engineering.