Improving perceptions of STEM careers through informal learning environments

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Abstract

Purpose – This paper investigated the impact a camp on informal science, technology, engineering and mathematics (STEM) had on students' perceptions of STEM fields and careers.

Design/methodology/approach – A quasiexperimental design was used to assess students' perceptions toward STEM fields and careers. Secondary students ($n = 57$) who participated in the STEM summer camp completed STEM projects, went on lab tours and attended panels during the one- or two-week residential camps. Students completed a STEM Semantics survey to assess their perceptions prior to and after attending the camp. Descriptive statistics, Cohen's d effect sizes, paired sample t-tests and Pearson's correlation were conducted to analyze the data.

Findings – Results suggested that although there was no significant change in students' dispositions toward each individual STEM field, there was a statistically significant improvement of students' perceptions of STEM careers ($p = 0.04$; $d = 0.25$). Furthermore, the results of the Pearson's correlation indicated that there was a statistically significant positive association between perceptions of a STEM career and perceptions in science, mathematics and engineering.

Research limitations/implications – This suggests that various components of the informal learning environment positively contributed to students' perceptions toward STEM careers. Implications from the study indicate that when students are engaged in hands-on science or STEM PBL activities and have opportunities to be exposed to various STEM careers, their perceptions of STEM pathways will improve.

Originality/value – These results may influence future curriculum and the organization of future STEM camps by encouraging teachers and camp directors to integrate practical hands-on STEM projects and expose students to potential STEM pathways through lab tours and panels of STEM professionals.

Keywords Self perception, Mathematics education, Science education, STEM, STEM careers, STEM camps

Paper type Research paper

Introduction

As the demand grows for skilled labor in science, technology, engineering and mathematics (STEM) fields, so too does the need to improve educational practices in these same fields (Litzler *et al.*, 2014). However, improving these practices is not the only change necessary to bolster the future STEM workforce of the United States. Christensen and Knezek (2017) also note that as students' interests in STEM increases, their desire to pursue a STEM career grows. Therefore, it is important to understand students' current dispositions toward STEM fields in order to better strategize future STEM education and outreach.

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There are several factors that influence a student's desire to pursue STEM studies and careers. Researchers have determined that grade level is one of these and that dispositions toward STEM fields vary among students of different grade levels (Christensen *et al.*, 2014; Knezek *et al.*, 2011). Furthermore, students may choose not to pursue STEM careers because they are not exposed to career options (Christensen and Knezek, 2017), not aware of the knowledge needed for STEM degrees or informed of the financial benefits of STEM careers (Prieto and Dugar, 2017). Providing students with access to STEM content and information regarding potential STEM careers may address these above-mentioned factors, but such an intervention should begin early in a student's career to improve the chances that educators make a lasting impact on students' dispositions toward STEM careers (Christensen and Knezek, 2017; Prieto and Dugar, 2017; Sari *et al.*, 2018). Engagement in an informal STEM camp during their secondary education may provide students with the knowledge of various STEM fields and degrees and the benefits of STEM careers they may not have learned about otherwise. Therefore, the purpose of this research is to determine if participating in an informal STEM camp improved students' perceptions of STEM fields and careers.

Perceptions of STEM and STEM careers

There is a growing need for more students to pursue STEM fields and careers to fill the demand for professionals in the STEM workforce. Providing students with access to STEM content and information regarding potential STEM careers should begin early in their educational career (Christensen and Knezek, 2017; Prieto and Dugar, 2017; Sari *et al.*, 2018; Tran, 2018). A student's STEM identity is heavily influenced throughout childhood and adolescent development and is directly related to a student's choice to pursue STEM careers (Dasgupta and Stout, 2014; Kim *et al.*, 2018). The development of a student's STEM identity is a result of a student's surroundings and their perceptions of whether or not they believe they fit the criteria for becoming a member in the STEM community (Kim *et al.*, 2018; Vincent-Ruz and Schunn, 2018). Because this process begins with a child's early STEM interactions and through their parents, these early experiences can greatly contribute or hinder students' persistence (Dasgupta and Stout, 2014). For young girls particularly, "mothers' (more than fathers') support predicts adolescent students' motivation to persist in science and math" (Leaper *et al.*, 2012, p. 270). Parents can be a significant influencer of a child's dispositions toward the STEM fields before the latter enters the education system. In addition to parents, researchers have found that exposure to STEM, specifically engineering, through toys at a young age directly impacted a student's interest in STEM fields (Fantz *et al.*, 2011; Maltese and Tai, 2010). The development of a student's perception of STEM can begin prior to elementary school and is heavily influenced by parents and the environment surrounding the student.

As children enter primary school, their perceptions of STEM fields begin to be influenced by their classroom environments and activities. For example, Tran (2018) immersed primary school students in computer science activities over a three-month period and found students realized the importance of learning STEM subjects for a future career. Development of positive perceptions toward STEM fields is seen to be highest at a young age when compared to secondary students' perceptions of STEM (Christensen *et al.*, 2014). Therefore, it is important to determine ways to continue this positive progression at various stages of education to support a long-term positive disposition toward STEM careers among students.

As students' transition from primary to secondary school, their decisions to participate or enroll in STEM-based activities are influenced by 1) their peers and 2) their evolving individual beliefs about STEM fields. Research has suggested that during middle school, students who held positive beliefs about STEM fields develop interest in potential STEM careers (Christensen and Knezek, 2017). In addition, research has indicated girls' dispositions toward STEM were impacted by their friends, demonstrating the influence that peers have on student interest in STEM fields (Dasgupta and Stout, 2014). For example, students may be more inclined to take an advanced science course if their friend is also in that course. Conversely, decisions to enroll in STEM courses during secondary school may go beyond the influence of peers; they may also be determined by students' inherent interest in STEM fields. For instance, one study showed that secondary students were more likely to take STEM courses if they were passionate about STEM-themed hobbies (Fantz *et al.*, 2011). The decision to take STEM courses is pivotal in the development of a student's disposition toward STEM fields and careers. Researchers investigated secondaryschool–aged students engaged in STEM problem-based learning or hands-on science activities and revealed that students' attitudes toward STEM careers increased significantly, particularly in engineering and technology (Çevik, 2018; Christensen and Knezek, 2017; Sari *et al.*, 2018). Studies done at the secondary level where exposure to STEM careers was the treatment showed a considerable increase in students' interests in occupations related to engineering and technology (Fantz *et al.*, 2011; Sari *et al.*, 2018). These studies suggest that exposure to STEM fields during secondary school is a major factor in whether or not students decide to pursue STEM careers though their decision to engage in STEM courses may be heavily influenced by their peers and their own inherent attitudes toward STEM-related courses.

Students' interests and perceptions of STEM fields alter as they get older due to many factors, such as parents, peers and early exposure to STEM. Although there is a pronounced drop in dispositions toward STEM among students as they transition from primary school to secondary school, student interest in STEM careers can be maintained throughout secondary school with adequate exposure to STEM courses and fields. Therefore, in order to maintain students' interest and positive perceptions of STEM fields throughout secondary school, educators should adjust their curriculum to garner students' engagement (Christensen *et al.*, 2014). Parents should continue to encourage students to pursue STEM careers and schools must offer opportunities for students to be exposed to the evolving and growing fields of STEM. Another way that schools can support STEM interests among students is to implement a highly engaging curriculum where students are actively participating in informal settings that allow and encourage parental participation.

Informal learning environments

For the purpose of this study, informal learning environments are educational experiences that take place outside of a typical classroom setting. There are several aspects of informal learning environments that foster 21st century skills such as communication, social skills, collaboration, creativity, technology literacy and leadership (Ghadiri Khanaposhtani *et al.*, 2018). When students have the opportunity to informally experience the curriculum in a real-world context, they have applied their academic knowledge in a new way. Field trips and extracurricular programs are examples of informal learning environments that allow students to explore modern topics and learn new concepts, thereby broadening their outlook of the STEM fields. These types of settings act as a catalyst for students to become interested in STEM-related fields and motivate them to pursue STEM-related careers. Field trips related to STEM fields allowed for a deeper understanding of STEM concepts because real-world experiences merged with students' prior academic knowledge (King and Pringle, 2019). Furthermore, a study of a group of girl scouts who were engaged in an informal learning environment, which focused on encouraging critical and creative thinking and exposing the girls to STEM careers showed that involvement with informal learning improved the girls' confidence to solve real-world problems and increased their interest in STEM-related fields (Burrows *et al.*, 2018). When students were engaged in out-of-school experiences like field trips, they were able to apply STEM content to their world and were more likely to increase and sustain their interest in STEM-related fields.

Another example of informal learning is participation in STEM camps. Typically, STEM camps promote the development of 21st century skills, especially those of communication, collaboration, social skills, creativity and leadership. Students who participated in STEM camps were challenged to effectively communicate and work with their peers toward a common goal (Ghadiri Khanaposhtani *et al.*, 2018; Bicer and Lee, 2019; Bicer *et al.*, 2015, 2018). As students collaborate with others during STEM camp activities, they are able to reflect on their mistakes, anticipate potential failures and take ownership of their learning (Vela *et al.*, 2019; Watkins *et al.*, 2018). In fact, the use of discipline-specific technology provided the students with a new skill set and also fostered the development of a scientific identity because they were using tools that scientists actually use in their careers (Ghadiri Khanaposhtani *et al.*, 2018; Kim *et al.*, 2018). In the study conducted by King and Pringle (2019), students were encouraged to showcase their findings to family and community members, which encouraged the development of social skills such as public speaking. Student participants were interviewed after participating in the I AM STEM summer program, and researchers found that their engagement in STEM continued throughout the year as students chose to visit scientific institutions, joined STEM-related clubs and even registered for other STEM camps (King and Pringle, 2019). The characteristics and informality of STEM camps promote the use of 21st century skills and can influence students to engage in educational experiences that change the way that they view the STEM fields.

Informal learning environments also provide more opportunities for students to make personal connections with what they learn. This was often accomplished at STEM camps when curriculum was specifically designed to provided real-world contexts and authentic experiences that deeply engaged students on a personal level (Bicer *et al.*, 2015, 2018; Ghadiri Khanaposhtani *et al.*, 2018; Vela *et al.*, 2019). As a result, students find the learning experienced at STEM camps enjoyable and often transfer that emotion to the STEM fields. They also often reflected on their experiences at STEM camps as being meaningful, authentic, fun, interesting, awesome, cool and creative (Ghadiri Khanaposhtani *et al.*, 2018; Mohr-Schroeder *et al.*, 2014). Other studies have shown that there was a statistically significant relationship between science and self-efficacy predicting interest in a STEM career (Bicer and Lee, 2019; Kwon *et al.*, 2019). This supports the idea that when curriculum is specifically designed to mimic the work of STEM professionals, students enjoy what they learn and they are able to see themselves pursuing these interests and possibly a career in a STEM field.

Although students' perceptions of the STEM fields have been studied in formal and informal settings, STEM education is an evolving curriculum where educators and researchers are attempting to find the best methods and practices to improve students' perceptions and interest in STEM. This current study deals with the effect of highly integrating STEM projects and exposes students to possible STEM pathways to influence their perceptions of STEM fields and careers. Results will contribute to the current literature by exposing methods or practices that may enhance students' perceptions of STEM.

Theoretical framework

Students' perceptions of classes, projects and careers are associated with and influenced by their learning environment. These associations between the learning environment and perceptions of STEM fields and careers influenced a student's educational decision to participate or enroll in STEM courses or majors (Bandura, 1986, 2012; Tosto *et al.*, 2016). In addition, these perceptions influenced students' performance in STEM courses and majors (Tosto *et al.*, 2016). Bandura's (1986, 2001, 2012) social cognitive theory, which focuses on the relationship between students' behaviors and their learning environment, aligns with the theoretical framework for this study and contends that perceptions may differ across various learning environments. Because informal learning environments, such as STEM camps, can often be more immersive than traditional formal classrooms, students' perceptions may be impacted on a greater scale in contrast to what the traditional classroom may offer (cf. Boedecker *et al.*, 2015; Ramey-Gassert, 1996). Furthermore, STEM camps may provide students with a long-term desire to persist in a STEM field because the focus of the camps includes integrating 21st century skills, such as problem-solving, teamwork and real-world applications (Bachman *et al.*, 2008). The informal learning environment a STEM summer camp offers allows students to take the initiative of their own learning and inspires participants to consider pursuing careers in STEM-related fields (cf. Vela *et al.*, 2019; Watkins *et al.*, 2018). This aligns with Bandura's (2001) conceptual belief that students are active agents of their learning and not passive bystanders. Students are able to act as such at STEM summer camps because they feel safe and confident enough to engage in challenging activities within the camp's informal learning environment.

Methods and procedures

In order to determine how a one-week STEM camp affected students' perceptions of STEM, a quasiexperimental study was designed to answer the following two questions.

RQ1. How does engagement in a one-week STEM camp affect students' perceptions of science, mathematics, engineering and STEM careers?

RQ2. How are students' perceptions of science, mathematics and engineering correlated to their perceptions of a STEM career?

Participants and setting

There were 57 secondary students who participated in this current study, which took place at a large university in the southwest part of the United States. Because it is important to clearly describe the demographics of the participants (American Educational Research Association, 2006), Table 1 contains participants' information. Participants were enrolled in a one-week residential STEM camp designed to immerse students in STEM fields and potential careers through projects, lab tours and panel discussions.

Factor	Total	Percentage
n	57	
Gender		
Male	30	52.6%
Female	27	47.4%
Race		
Asian	8	14.0%
African American	2	3.5%
Hispanic	11	19.3%
White	33	57.9%
Chose not to disclose	3	5.3%
Residency		
In Texas	55	96.5%
Outside of Texas	2	3.5%
Grade level		
Middle school (6–8)	18	31.5%
High school (9–12)	39	68.4%

Table 1. Demographics of study sample

Camp projects incorporated STEM project-based learning (PBL) activities to engage students in the nexus of science, technology, engineering and mathematics. Most of the projects were centered on science, engineering concepts, embedded mathematics and technology. Sample courses included engineering design process, physics, coding, SAT math and robotics, all of which made use of real-world examples to facilitate STEM learning. For instance, in physics, students designed a fidget spinner and were required to calculate its angular momentum and rotational kinetic energy. In addition, in an engineering design process class, students designed a roller coaster and were required to calculate the potential and kinetic energy at various points on the roller coaster. These experiences allowed students to implement several 21st century skills, such as communication, social skills, collaboration, leadership and creativity, while completing the STEM PBL projects. The informal learning environment of the camp went beyond the classroom. At the end of each day, students toured various STEM labs (i.e. the Cyclotron Lab, Wind Tunnel, Rainfall Simulator and the Electron Microprobe Laboratory) to be exposed to the possible opportunities for future STEM research and careers. Students also heard from a diverse group of STEM professionals to gain insight into potential STEM careers, during a panel. Specifically, students heard from local professionals from engineering and technology businesses and professors from the university.

Instrument

Participants were administered the STEM Semantics instrument developed by Christensen *et al.* (2014) as a pretest and posttest. The instrument included questions on students' dispositions for each of the following categories: science, engineering, mathematics and careers in STEM. Students were presented with five adjective pairs on a 7-point scale and were instructed to rate their perception of that particular area. Figure 1 represents the five adjective pairs provided for the science category. These same five adjective pairs were given in random order for the subsequent categories. Three of the adjective pairs (fascinating–ordinary, appealing–unappealing, and exciting–unexciting) were reverse coded during analysis to indicate that a higher score would be interpreted as having a positive perception toward the category. Students could score a maximum of 35 points for each category.

Data analyses

StataSE16 was used to analyze the data for the current study. Researchers first calculated Cronbach's alpha statistics for the data in hand to estimate reliability for the data in hand (see Cronbach, 1951; Nimon *et al.*, 2012; Thompson, 2002). Next, researchers calculated paired sample t-tests and Cohen's d effect sizes to determine if a one-week residential STEM camp had a statistically significant relationship with students' perceptions of STEM fields. The *a priori* alpha was set to 0.05 with a Bonferroni correction for any repeated univariate tests. Next, researchers conducted a correlational analysis to determine the relationships between each

To me science is:								
fascinating	1	2	3	4	5	6	7	ordinary
appealing	1	2	3	4	5	6	7	unappealing
exciting	1	2	3	4	5	6	7	unexciting
means nothing	1	2	3	4	5	6	7	means a lot
boring	1	2	3	4	5	6	7	interesting

Figure 1.
Science scale from the STEM Semantics survey

category. The researchers first conducted a multiple regression with the independent variables (postscience, postmathematics, and post-ngineering perceptions) regressed on perceptions of STEM careers. Researchers then predicted perceptions of STEM careers based on the results from the regression analysis. Finally, researchers conducted a Pearson's correlational analysis using the predicted perceptions of STEM careers and perceptions of science, mathematics and engineering. Statistical significance was set to 0.05 with a Bonferroni correction.

Results

Researchers calculated reliability levels for each category. Cronbach's alpha results for each category ranged between 0.91 and 0.93 for the data in hand (see Table 2), which were satisfactory (Cronbach, 1951; George and Mallery, 2003). Means on the pretest indicated that students came in with high perceptions toward STEM fields and careers and the maximum score for each category was 35 points. Means for perceptions of STEM careers were the highest on the pretest at 31.56 (SD = 5.78). The means for perceptions of mathematics were the lowest on the pretest at 28.72 (SD = 6.67). The means for perceptions of both science ($\bar{x}$ = 30.75, SD = 5.64) and engineering ($\bar{x}$ = 30.18, SD = 6.28) were scored similarly on the pretest. The means from pretest to posttest increased in all categories (i.e. science, mathematics, engineering and STEM careers, see Table 3). The ranking order remained the same as the pretest; perceptions of a STEM career had the highest mean, and perceptions of mathematics had the lowest.

Research question 1

Effect sizes and paired sample t-test scores were calculated to determine the effects of a STEM camp on students' perceptions of STEM fields and careers. Effect sizes for all categories ranged between 0.11 and 0.25. Perceptions of a STEM career were a quarter of a SD higher on the posttest (d = 0.25). In addition, only perceptions of a STEM career statistically significantly improved from pretest to posttest (p = 0.04). No other results were statistically significantly different.

Research question 2

Next, researchers wanted to determine if student perceptions of science, mathematics and engineering were correlated to their perceptions of a STEM career. The multiple regression

Category	Cronbach's α
Science	0.93
Mathematics	0.91
Engineering	0.92
STEM careers	0.91

Table 2. Reliability results by category

Category	Pretest $\bar{x}$	Pretest SD	Posttest $\bar{x}$	Posttest SD	Cohen's d	t	p
Science	30.75	5.64	31.82	4.68	0.21	1.73	0.09
Mathematics	28.72	6.67	29.88	5.70	0.19	1.76	0.08
Engineering	30.18	6.28	30.86	6.19	0.11	0.96	0.34
STEM careers	31.56	5.78	32.82	4.40	0.25	2.08	0.04*

Note(s): $^*p < 0.05$

Table 3. Paired sample t-test results by category

model, with all three predictors (postscience, postmathematics and postengineering perceptions), produced an adjusted $R^2 = 0.238$, $F(3, 53) = 6.81$, $p < 0.0006$. Predicted scores for STEM careers were calculated and used for the Pearson's correlational analysis. Results of the Pearson's correlation indicated there was a statistically significant positive association between perceptions of a STEM career and perceptions in science ($r(57) = 0.77$, $p < 0.0001$), mathematics ($r(57) = 0.74$, $p < 0.0001$) and engineering ($r(57) = 0.73$, $p < 0.0001$).

Discussion

The focus of the current study was to determine if participation in a one-week informal STEM camp influenced students' perceptions of STEM fields and careers. Prior research has indicated that perceptions may be impacted by parents, teachers, peers and students' learning environment (Christensen *et al.*, 2014; Dasgupta and Stout, 2014; Fantz *et al.*, 2011). We framed this study around Bandura's (1986, 2001, 2012) social cognitive theory, which suggests that students' behaviors are influenced by their learning environment. Furthermore, research has shown that students' actions or behaviors are inherently driven by their perceptions (Bandura, 1986, 2012; Tosto *et al.*, 2016). For example, if students have positive STEM perceptions, they are more inclined to enroll in STEM courses. Therefore, assessing students' ($n = 57$) perceptions after participating in a one-week informal learning environment will aid researchers in determining effective practices that may positively influence students' perceptions toward STEM fields and careers.

Results from the first research question indicated that students' perceptions of STEM careers improved as a result of participating in a STEM camp. These results imply that engagement in STEM summer camps positively exposed students to a variety of STEM career options. They also imply that students may have realized there are benefits associated with having a STEM career that they may not have been aware of before this experience. Even though results from the study do not show a statistically significant improvement of perceptions in science, engineering and mathematics, this does not mean the camp did not have any impact on these perceptions. This lack of a significant improvement could be due to one or both of the following reasons. First, students who attended the STEM summer camp already had very high perceptions of STEM fields, and there was little room for improvement. Second, students' perceptions of science, engineering and mathematics could be harder to change in a short amount of time because of the strength of their prior perceptions of these fields. Because students may not have been equipped with information about various career opportunities, their perceptions of STEM careers may not have initially been as strong as their perceptions of science, engineering and mathematics; thus, students showed the greatest improvement in their perceptions of STEM careers.

Results from the second research question showed strong relationships between perceptions of science, mathematics and engineering with perceptions of a STEM career. These results align with previous research (see Christensen and Knezek, 2017; Kwon *et al.*, 2019; Sari *et al.*, 2018), which states that engagement in hands-on science or STEM PBL activities will increase interest in a STEM career. Students were engaged with STEM PBL activities during the STEM summer camp; however, it was their perceptions of science that had the strongest association with positive perceptions of STEM careers. Even though important mathematics, technology and engineering objectives were embedded in STEM PBL activities, students tended to view the activities as science-focused. Furthermore, science fields were prominently represented through the STEM lab tours and by professionals during panels. Therefore, despite the fact that perceptions of STEM careers and perceptions of mathematics and engineering were significant, students may not have fully valued mathematics and engineering during the PBL projects or may not have realized that STEM labs and professionals were actually focused on engineering, technology or mathematics. Overall, findings from this study indicate that engagement in an informal STEM learning environment that highlights various STEM labs, careers and projects can positively influence students' perceptions of a STEM career. In addition, it identifies a significant association between perceptions of science, mathematics and engineering and perceptions of a STEM career. If the goal is to create a diverse competitive STEM workforce, then it should begin with improving perceptions of science, mathematics and engineering among students.

Conclusion

The purpose of this study was to determine the impact a one-week STEM summer camp had on students' perceptions of science, mathematics, engineering and STEM careers. Prior research has indicated the growing need for STEM professionals could be caused by students' lack of knowledge about career options and the financial benefits of STEM careers (Christensen and Knezek, 2017; Prieto and Dugar, 2017). The overall results from the current study indicate students' perceptions of a STEM career improved after attending the camp. This could be attributed to the engaging STEM experiences, such as lab tours and STEM panels, that students participated in during the camp. These experiences exposed students to potential STEM career options and the benefits of these careers. These results align with prior research, which indicated when students are exposed to STEM career it enhances their interest in ultimately pursuing these careers (Blotnicky *et al.*, 2018). Furthermore, results indicated that science, mathematics and engineering perceptions had a strong relationship to perceptions of STEM careers. Therefore, the more students are engaged in hands-on science or STEM PBL activities, which integrate the individual disciplines into one culminating interdisciplinary project, the higher their perceptions of STEM pathways.

Educational and scientific importance of the study

The results of the study indicate a positive relationship between engagement in a STEM camp and potential interest in a STEM-related career. These results can influence the curriculum and organization of future STEM camps by encouraging directors to develop hands-on activities and cultivate rich, informal learning environments that provide authentic experiences to highlight careers in the STEM fields. These ideas could also extend into the more formal learning environment of schools. If science, technology, engineering and mathematics teachers can see the impact of informal learning, they may be encouraged to incorporate authentic informal learning methods into their classroom. Incorporating authentic experiences such as PBL activities, field trips to STEM-related sites or inviting guest speakers from the fields to speak in class could potentially increase student interest in STEM fields. Overall, the development and research of STEM camps can potentially evolve STEM education as a whole and encourage students to pursue careers in the continually expanding scientific fields.

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