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From STEM to STEAM: Students' Beliefs About the Use of Their Creativity

Abstract

To be successful in a STEM career, not only STEM knowledge and skills but also creativity is required. Therefore, the arts have been integrated into STEM disciplines and subsequently designated as STEAM education (Sousa & Pilecki, 2013). One example of informal learning environments that STEAM education provided is a summer camp. In this study, middle and highs school students' use of their creativity in the Project-based Learning (PBL) courses was examined to determine students' belief about the use of the arts in STEM activities. The results showed that students believed that they used their creativity in eight of the nine classes.

Keywords

STEM education, STEAM education, Creativity

Cover Page Footnote

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From STEM to STEAM: Students' beliefs about the use of their creativity

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Introduction

Science, technology, engineering, and mathematics (STEM) knowledge and skills are critical for students to become part of the 21st century workforce. The desired skills for today's workforce include the use of an interdisciplinary approach to problem solving, technology, innovation, and communication with multiple media tools (Young, House, Wang, Singleton & Klopfenstein, 2011). Because there is a high demand for workers who have these skills in addition to STEM content knowledge, policymakers and other stakeholders focused on STEM education in an effort to increase the number of students pursuing STEM degrees and careers (National Academies of Science, 2007; Presidents' Council of Advisors on Science and Technology, 2010). While these actions continue, researchers have pointed out the importance of artistic skills in the STEM workforce (Madden, Baxter, Beauchamp, Bouchard, Habermas, Huff, Ladd, Pearon, & Plague, 2013; Keefe & Laidlaw, 2013; Kim, Kim, Nam, & Lee, 2012). For instance, one technology entrepreneur and former media/entertainment executive indicated the importance of the integration of STEM and art from the viewpoint of creativity by stating:

> *"As an executive and entrepreneur sitting on both sides of the creative/technology fence, I need to hire technologists who know how to collaborate in teams, express themselves coherently, engagingly and persuasively, understand how to take and apply constructive criticism, and how to tell a good story. I don't find these kids sitting alone at a lab table or buried in an algorithm. I find them taking art classes to understand how color and light really work…*" (Tarnoff, 2010, para. 8)

Therefore, the involvement of the arts with STEM is essential to overcome 21st century problems with a complete set of knowledge and skills that work in concert to provide the most effective solutions possible.

The integration of the arts into STEM education resulted in a new acronym STEAM, derived from STEM + Arts. The art aspect of STEAM was commonly referred as creativity in education (e.g., Land, 2013; Kang, Jang, & Kim, 2013; Kim et al., 2012; Madden et al., 2013; Sousa & Pilecki, 2013). Projects requiring creativity with the knowledge of STEM disciplines have gained popularity in recent years. For example, 3D printer use in project-based learning (PBL) activities showed the need for STEM knowledge and creativity to design more sophisticated products. PBL instructional strategies require students to produce an item (e.g., a prototype of a bridge or robot, a report or presentation for a professional community). When these types of projects are considered, more STEM PBL activities supported by the arts gain value and importance in formal and informal learning environments. The current study sheds light on the growing interest in STEAM. The purpose of this study is to examine middle and high school students' perceptions about the use of their creativity in STEM projects that were generated in a STEM summer camp.

Science, Technology, Engineering, Art, and Mathematics (STEAM)

While STEAM education has been developing, it is essential to understand why STEM needs to change to STEAM. STEM and the arts were long seen as opposite sides by the public (Sousa & Pilecki, 2013). However, the combination of these seemingly opposite sides brings the variety and diversity that are necessary for innovative product design. For instance, the characteristics of STEM are objective, logical, analytical, reproducible, and useful whereas the characteristics of the arts are subjective, intuitive, sensual, unique, and sometimes considered frivolous (Sousa &

Pilecki, 2013). Science and the arts complement each other because "science provides a methodological tool in the art and art provides creative model in the development of science" (Kim et al., 2012, p.2). In the real world, people possess and employ the characteristics of both sides; thus, the opportunity to utilize both characteristics should be included in education as well. For instance, when an architect designs a building, she needs to use creativity to make the building appear interesting and pleasant to those who work there or do business there as well as ensuring structural soundness. Musical instrument makers need to be precise with the mathematics and science required for pitch accuracy, but they also use their aural abilities to create tone qualities that are pleasing to the ears of the audience. STEAM education provides many opportunities for students to improve themselves in several areas, due to the advantages of the arts. These advantages are: a) development of cognitive growth, b) improvement of long-term memory, c) enhancement of social growth, d) reduction of stress, e) increasing the appeal of subject areas, and f) promotion of creativity (Sousa & Pilecki, 2013). When these advantages are taken into consideration and embedded in STEM education, it prepares students for todays' challenges. Research findings demonstrated that if the arts were included in science fields, students could be more interested in STEM fields (Kang et al., 2013), activities with experts could affect their career decisions (Keefe & Laidlaw, 2013) and STEM fields could be more appealing to students (Land, 2013).

Creativity

The "A" in the STEAM mostly referred to creativity in the education field (e.g., Kang et al., 2013; Kim et al., 2012; Madden et al., 2013; Sousa & Pilecki, 2013). Creativity includes divergent thinking (Madden et al., 2013; Sousa & Pilecki, 2013), and divergent thinking leads to more than one solution to a problem, which is a very important skill. Creativity also results in a product, and it is not only thinking but also "producing something novel" (Sousa & Pilecki, 2013, p. 50). Therefore, in the educational environment, students should improve their creative thinking skills because this is an essential skill for their future careers. Fostering creativity with activities in the learning environment is crucial. Research results demonstrated that activities requiring creative thinking resulted in positive outcomes. They enhanced students' self-reflection (Autry & Walker, 2011), increased advanced thinking skills (Hargrove, 2011), and strengthened collaboration with others (Crow, 2008). Thus, it is vital to provide activities such as PBL for students to improve their creativity in formal and/or informal learning environments.

Informal Learning Environments

Informal learning environments provide opportunities for supportive teaching and learning in addition to learning that takes place in formal school settings. There are different types of informal learning environments, and one of them is summer camp (Fenichel & Schweingruber, 2010). A myriad of summer camps have been provided in the United States (U.S.) in different fields such as leadership, sports, or academics. One type of camp is related to STEM learning. By attending STEM camps, students had an opportunity to understand and learn STEM fields in a more attractive and interesting way (Dave, Blasko, Holliday-Darr, Kremer, Edwards, Ford, Lenhardt, & Hido, 2010; Davis & Hardin, 2013). With a need for a greater number of STEM graduates, increasing the numbers of STEM camps in the U.S. was a logical approach. Offering STEM camps is a very effective way to increase the number of students who would like to pursue a STEM career. In this way, students could attend courses and participate in projects about STEM fields, and their interest in STEM could be enhanced.

In STEM camps, students are asked to participate in projects. These projects heavily focus on STEM subjects (Authors, 2013). However, projects in STEM camps require not only prior or existing knowledge but also creativity that requires an artistic perspective (Authors, 2014). Therefore, STEM projects actually include art in them. Art helps students to develop a subjective perspective while science created an objective one, and students need both to make informed decisions (Sousa & Pilecki, 2013). There are many advantages to integrating the arts into STEM subjects and creating STEAM (science, technology, engineering, art, and mathematics), such as developing cognitive growth, increasing long-term memory, and encouraging creativity (Sousa & Pilecki, 2013). Studies showed that if the arts were included in science fields, students could be more interested in STEM fields (Kang et al., 2013), activities with experts could affect their career decisions (Keefe & Laidlaw, 2013) and STEM fields could be more appealing to students (Land, 2013).

Purpose of the study

Even though inclusion of Arts disciplines into STEM disciplines has remained on the agenda for seven years, the studies focused on STEAM are sparse. The present study was conducted to shed light on STEAM education in an informal learning environment. In the current study, students' perceptions about how they used their creativity in their STEM projects were examined. They participated in several STEM PBL projects in the two-week long STEM summer camp. They had opportunities to use their creativity in their products in many courses. Their belief about the opportunity of the use of creativity in a STEM summer camp was surveyed before the courses were given. At the end of the camp their opinions about whether they had used their creativity on their projects were solicited.

Method

Participants

Participants (N=104) were 7^{th} through 12th grade students who attended a two-week summer camp that included a variety of mini-courses, most of which resulted in products that students designed and created. There were 61 male and 43 female students. The number of students according to their ethnicity was: African American (N=12), Asian (N=10), Hispanic (N=29), Indian (N=3), and White (N=5.0)

Intervention

Participants participated in a two-week long STEM-focused summer camp. During the camp, university faculty from different departments (e.g., civil engineering, physics, and education) taught the content with engaging PBL activities. The PBL activities provided in the camp for students to involve were: building bridges with popsicle sticks and glue, making lip gloss with organic materials, preparing a video that explained their (i.e., students) products they created during the PBL activities, planning a brochure about their other PBL outcomes, and designing an object with 3D modeling software (i.e., computer aided design), creating an application design for cell-phone, and using Legos to build robots. Students were able to print their 3D designs with a 3D printer. The projects were all subject to criteria for a well-defined outcome and constraints on the ill-defined task (Authors, 2013). Students were able to test their bridges and after testing, they calculated the efficiency rate, which was the weight that the bridge could carry divided by the bridge’s mass. The efficiency rate of the bridge, creative design, and realistic bridge design were judged, and awards were presented to the winners.

Data Analysis

To understand students' perceptions about the creativity usage in activities, questions on a Likert scale and an open-ended question were asked. The frequency of the answers was reported and students' answers were classified according to the courses they identified that required creativity and the ways they used creativity in designing their products.

Results

Students' perceptions about usage of their creativity in STEM projects were explored in the survey. Sixty-four students replied to the open-ended question, "If you had an opportunity to use your creativity, explain how you used creativity in your project(s)". Students' answers were classified under the eight mini-courses identified as providing opportunities for using creativity. These classes were: 1) 3D design, 2) bridge building, 3) designing a brochure, 4) making a video, 5) creating a robot, 6) designing a phone application, 7) formulating lip gloss, and 8) creating a cipher message.

Forty-three students asserted that they used creativity in the computer aided design course. In this project, instructors taught students how to use 3D modeling software, and students designed and printed their own products (see Figure 1). There were some limitations in the course in terms of 3D printer capability such as the product that students designed had to meet the criteria of fitting on the build plate of the 3D printer. Students enjoyed making their own designs and were interested in building an object that included their creativity. Examples of students' answers about computer aided design and use of their creativity is represented in Table 1.

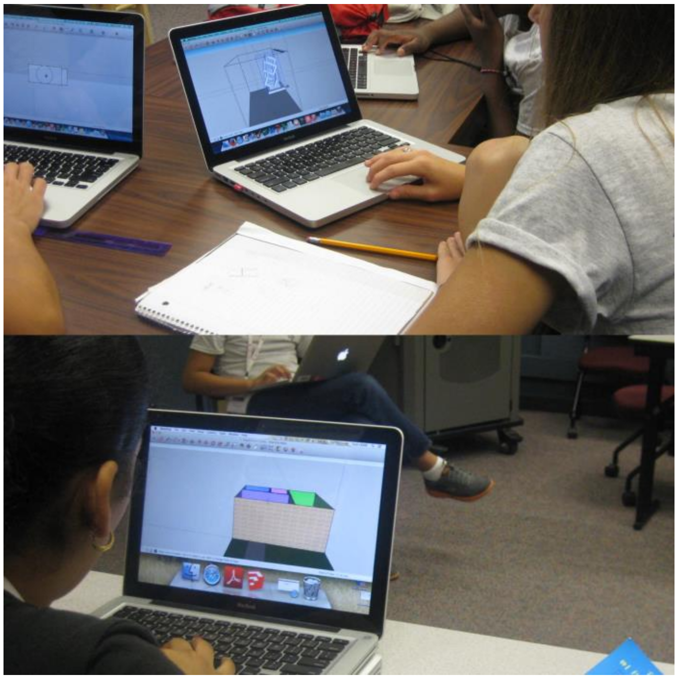

Figure 1. Representative images of students' object design in a 3D modeling software

The second most frequent answer was about the construction engineering course. Students built bridges according to constraints given in the PBL handout. They were allowed to use only a limited number of popsicle sticks and glue (see Figure 2). The bridge had to meet requirements that included specific distances from abutments of the bridge and the width of the bridge. Students used their creativity in this activity, and they were keen to create a bridge that was different from other groups; therefore, they used their creativity both in designing a bridge that they believed would bear the most weight and was unique. Some examples of students' answers are represented in Table 1.

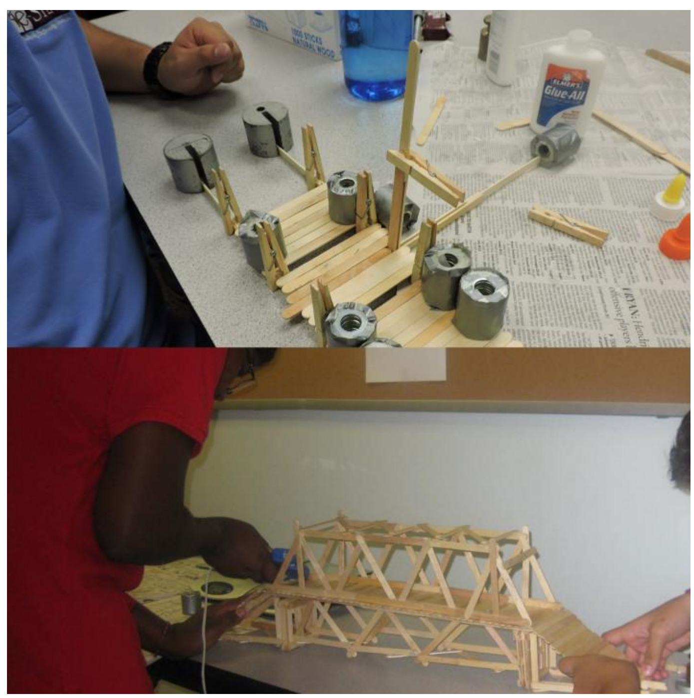

Figure 2. Students work on building bridge with given materials

Students were assigned to one of two marketing classes. One class was multimedia marketing, and the other was print marketing. In these classes, students were expected to market their products that were created in other PBL courses. In the multimedia marketing class, they filmed and edited a movie by using iMovie software. In the print marketing class, students learned how to design a tri fold brochure. In both classes, they used their creativity to propose the best and most eye-catching presentation to sell their PBL products. Table 1 includes examples of students' opinions about using their creativity in these classes.

Robotics, lip-gloss production, application design, and cryptography were other courses through which students affirmed that they used their creativity. Examples of students' perceptions about creativity in these courses are presented in Table 1.

Table 1

Students' Answers about Use of Their Creativity in Classes

Classes (Frequency)	Examples from students' answers to the open-ended question
3D design (43)	• I made a *tank in sketch up* that was unique because the way I made it. • I was in *the Computer Aid Design* class, so I was able to make whatever I wanted on *Sketch up*. I was able to use my *creativity* then. • When I created *a 3-D object in my Computer Aided Design* class, I used my *artistic ability*.
bridge building (18)	• I used my *creativity in bridge building* and *computer aided design*. In bridge, I wanted the creativity award so I was being creative. In computer aided design I was being creative because I was designing an abstract sculpture. • *Bridge designs* allowed for a *creative project* that would be tested to see how your idea performs. *3D printing* allowed you to *bring your dreams to life and express yourself through artistic* means • I used it when I *built the bridge by using shapes and also coloring* it.
designing brochure (10)	• Created a *brochure* for biology • Mostly in my *bridge* or my *3-D project* or even my *brochure*. I created a *solar cannon in my brochure* from the future and even created a *futuristic car with 3-D software*. • I used my creativity in activities such as making my own business in print marketing.
making video (9)	• I used my *creativity* to *make a 3d object* and *to make a video* in iMovie. • I used in both the *multimedia project class* and the *3D software* and *printing class* • Drawing *pictures*, choosing *my own music*, making things colorful (in multimedia marketing class)
creating a robot (5)	• We had to make *robots* from scratch that utilized our use of creativity. • I built a *robot* with 2 NXTs *instead of one like everyone else*.
making lip gloss (2)	• We used it (creativity) in multimedia with the videos, cosmetic science with *creating lip gloss*
designing phone application (1)	• I used my *creativity* when I made an (phone) *application* about lip gloss and shaving cream. I also made a *brochure* and planted seeds such as chia & sprouts.
creating cipher message (1)	• Used to *create hard codes* for the coding scavenger hunt. I had to improvise on the *bridge project* and my team was constantly in search of a *creative, more efficient solution*.

Conclusion and Discussion

Although STEM is important for progress in today's society and global competition, the omission of the arts from the educational system would clearly be a colossal mistake. Well over half the students in the study indicated in the survey that they would be more interested in STEM careers if they were able to use creativity in the job itself. Most of the students indicated a belief that STEM careers required creativity, but the number of those who believed problem solving required artistic solutions increased after the STEM camp experience. The individual comments showed that the students were well aware of their use of creative and artistic solutions in a variety of ways. One might expect students who chose to attend a STEM camp to have a more realistic idea of STEM careers than the general population. However, often parents elected to send students to the camp; students did not necessarily choose a STEM camp. The experiences at the STEM camp gave students opportunities to design products and solve problems using STEM content knowledge and creativity combined, experiences not often gained in formal school settings. The implications for education are twofold: 1) the arts should preserve or regain their prominence in the educational system, and 2) opportunities should be provided in formal school settings for students to use both creativity and logical thought processes in solving problems. Engagement in the arts has been shown to have benefits emotionally, giving the arts an importance on their own, outside STEM. However, opportunities to participate in the arts also supply students with creative outlets that will support and enhance their problem solving skills. By giving students the tools they need to solve 21st century problems from a variety of perspectives and using a variety of approaches by integrating skills from the arts and STEM, future scientists and engineers will fully understand the benefits and importance of STEAM for our world.

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