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Lending a Helping Hand: Learning to Help and Develop Socially Conscious Scientists

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In recent years, there has been an increased focus on STEM (science, technology, engineering, mathematics) education. 3D printing in the classroom can provide immersive, challenging and tangible experiences to build a stronger understanding between the subjects to help students see themselves as capable engineers, mathematicians, and scientists. This study investigated students' self-perception and attitude towards STEM activities and carriers from participating in an afterschool STEM program. Results show that students were able to better understand the subjects and demonstrated positive changes in their attitude towards STEM subjects and saw themselves as successful future artists, mathematicians, and scientists.

Keywords*:* Self-perception, STEM, integration, 3D printing, prosthetics, attitude

As classrooms become more culturally and linguistically diverse, educators are experiencing more difficulties to maintain students' attention. In response to this problem, teachers are relying on alternative strategies to make teaching materials more relevant to students (Duatepe-Paksu & Ubuz, 2009; Jackson, 1997). An, Kulm and Ma (2008) suggest that the integration of art and mathematics and more specifically, the use of music "can provide an alternative approach to students who have difficulty learning mathematics in traditional ways" (p.97). Nalder and Northcote (2015) take a different approach and looked at the impact that movement-based activities had on students' concentration and engagement in all academic areas. In addition to increasing their understanding of the content, integration also gives us the opportunity to develop student's love of learning, but more importantly, increase their critical thinking skills (Costley, 2015).

However, we must make sure that through carefully crafted lessons and programs, students have the opportunity to respond to real world questions to develop their 21st century skills (Baker & Galanti, 2017). According to Bicer and Lee (2019), the United States is experiencing a decrease in the number of students in Science, Technology, Engineering and Mathematics (STEM) fields. This means that in the near future, the United States will have an inadequate number of qualified professionals to satisfy the demand in those fields. For this reason, we must introduce students to STEM as early as possible. We must not only pique but also develop their interest at an early age.

Our current way of life is governed by technology, built by engineering and science and run by mathematics. As Barone (2018) states that, STEM is important because our world depends on it. Manufacturing, communications and every facet of our lives depend on STEM. However, STEM is not just the conglomeration of Science, Technology, Engineering and Mathematics. It is how we teach and how we apply all these subjects in a way that resembles real life.

To give students a better understanding of the complexities of our world, teachers are focusing their efforts on the emergent technology tools. 3-dimensional (3D) printing is one of the new technology tools in the classroom. Schools are investing in this technology to make STEM education fun and engaging and also to add a whole new dimension to the student experience with a variety of possibilities (Peterson, 2015). Through play and visualization, students can examine replicas of fragile artifacts. For example, Kindergartners can print nests designs to learn about birds. 3D printing can help students explore the connection between their imaginative designs and a machine that will bring them to reality (Peels, 2017).

Purpose and Research Questions

The purpose of this study was the analysis of an attitudinal survey of students participating in an afterschool Science Club or STEM program in several schools across a school district. Although all sites used a variety of projects such as robotics, rocketry or prosthetics, they were all guided by the Next Generation Science Standards (NGSS Lead States, 2013). Another commonality is that for many of the students, this was the first-time experiencing science involving hands-on interactive projects.

As we designed the hands-on lessons and activities, the main question was if we could change the students' perception of themselves as scientists, mathematicians and artists. The lessons were designed under the assumption that students are better able to understand and learn the STEM principles as they actively participate in finding solutions to the problems presented.

This research project was designed and conducted to answer the following questions:

1. What are students' current attitudes towards STEM activities and careers?
2. Does participation in an afterschool STEM program change students' self-perception and attitude towards STEM careers?

Theoretical Framework

Today's students are constantly inundated with enormous amounts of information from sources such as radio, television, electronic games and the Internet which, coupled with the more diverse economic, cultural and academic students' background exponentially increases the level of difficulty in maintaining students' interest (Jackson, 1997). In their efforts to engage and motivate the students, teachers employ a wide variety of traditional and avant-garde strategies to benefit all students in their class.

However, not all strategies work for all students and teacher are left to decide which strategies to use to benefit the highest number of students. Some classroom teachers offer classics such as peer tutoring, small group instruction and visual aids. Others however, use and report good levels of success with alternate forms of assessment and alternate types of strategies such as cooperative learning, creative dramatics, music, computer centers and even a makerspace.

Integration and the arts have become increasingly more difficult to define in the last 30 years because of the artificial boundaries set among academic subjects (Russell & Zembylas, 2007) and we must grapple with "the changing nature of the arts and what counts as the arts" (Gadsden, 2008, p.29). Other challenges have been the degree of which art is integrated into the curriculum, how educators interpret the needs of their students and because teachers have different "view points and approaches when integrating the arts and core subjects" (Gadsden, 2008, p.1). More recently, the debate and confusion derive from the multiple meanings of what an integrated curriculum is. In addition, many teachers feel they lack the confidence, training and time to develop and implement an integrated curriculum especially when it involves working with a combination of mathematics and science.

Fortunately, however, difficulties such as boundaries and confusing definitions have not deterred educators from using "two or more disciplines in ways that are mutually reinforcing" (Russell & Zembylas, 2007, p.289). Even in this era of economic downturns, teacher layoffs and massive economic cuts to school budgets, teachers still manage to introduce students to the wondrous worlds of art and science without sacrificing precious instructional time.

The idea of an integrated curriculum is nothing new to teachers and as more demands are added to the curriculum, educators have to find creative ways to fit such demands into the instructional day. In addition, budget cuts are creating a reduction in personnel, which in turn is causing a reduction in the number of subjects being taught and general education teachers are required to teach subjects previously taught by specialists such as art teachers, physical education coaches and music teachers.

Jackson (1997) stated that through drama, students are able to collect "primary and secondary evidence which contributes to individual knowledge" (p.6). According to Jackson, students involved in dramatic play developed better communication skills as they learned to interact with other students, thus becoming more cooperative. In addition, Jackson argued that dramatic learning involves concentration, imagination, emotions and intellect, among other components. Learning then, occurs in the process of developing these areas and through the opportunity for social interaction they provide. Fiske (as cited by An, et al., 2008) agreed and adds that the arts not only connect students to themselves but also connect their learning experiences to the world.

As another component of the arts, music is also an effective strategy, stated Hill-Clarke and Robinson (2002). It helps improve students' attention span, vocabulary acquisition and creativity. The authors also cited Gardner's multiple intelligences as one of the main reasons to utilize music as a strategy because the musical intelligence is the earliest intelligence to emerge. They also claimed that music improves learning in academic and social areas in addition to create and enhance cultural awareness. Russell and Zembylas (2007) cited their own experiences integrating the use of poetry and fish painting as well as antislavery songs to discuss slavery as a moral issue and to stimulate emotions and observation in science with older students.

Kocabas (2009) examined the effect of using songs on students' multiple intelligences, attitudes and achievements with positive results in a study of 286 third graders in Turkey. Kocabas found that in addition to a reduction on the level of student anxiety there is a positive correlation between music and mathematics and an increase in their academic performance.

Contrary to popular thinking that music integration is more common in the elementary curriculum (Colwell, 2008), Kocabas (2009) mentioned a study done at the University of North Carolina involving a musical game, which helped students' mathematics scores to improve. Russell and Zembylas (2007) cited their own experiences integrating the use of poetry and fish painting as well as antislavery songs to discuss slavery as a moral issue and to stimulate emotions and observation in science with older students.

Learning occurs when the pupil has a genuine deep understanding of the problems they are trying to solve (Jackson, 1997). The integration of the arts, mathematics and science can serve as a catalyst for students to discover, understand and to enjoy mathematics because "…regardless of their personal characteristics, backgrounds or physical challenges, all students must have the opportunities and support to learn" (An, Kulm & Ma, 2008, p. 96).

Research Methods

Research Site

Nine elementary schools from a district in Southern California participated in this study. The School District is located ten miles east of the

Los Angeles Civic center on the border of East Los Angeles and provides educational services to more than 26,000 students in grades K-12 in 17 elementary, 7 intermediate, 4 high schools and four adult schools. The School District serves a diverse student population from the cities of Bell Gardens, Commerce, Montebello, portions of Downey, Los Angeles, Monterey Park, Pico Rivera, Rosemead and South San Gabriel and is one of the largest school districts in Los Angeles County.

Participants

The student population of the district is 95.6% Hispanic/Latino. In addition, there is a 1.8% Asian population, 1.0% Anglo (non-Hispanic) and the remaining 1.6% of the population is comprised of African American, Native American, and Filipino ethnic groups. Forty-nine percent of the district's students are classified as English Language Learners (ELL). About one third receive Aid to families with Dependent Children (AFDC), Cal Works, which provides temporary financial assistance and employment to families with minor children who have income and property below State guides, and about 90% of all students in the school district receive free or reduced lunch, which is the poverty indicator established by the federal government.

Nine of the district’s elementary school participated in this after school program. Each of these schools has two (2) STEM teachers per site and they have received training from the UCLA Science Project and other consultants. Each STEM teacher has between 20 and 25 students who were selected by their homeroom teacher based on a combination of academic performance and interest in STEM fields or specific careers. Most of the students are fifth graders with a sprinkling of high performing fourth graders for a total of 242 students.

Procedure

Teachers used this opportunity to infuse their instruction with STEM activities in addition to introducing the concept of applying science to address a real-life issue in their community or school. At one of the schools, after several days of rain, some students noticed that water would puddle around school. They also knew, based on news reports and class discussions that California is in a drought. Together with their teacher, they decided to find ways to reduce water consumption and, more importantly, how to collect and use rainwater around their school. Their observations, discussions and research lead them to design and build a water collection system around their school, which helps them collect and store rainwater for projects such as irrigation throughout the school as well as for classroom projects.

In our school, the students decided to help a schoolmate whose fingers on one hand had not develop properly at birth. Although she is well adjusted and has develop many friendships, she could not participate in certain activities. Doing independent work, two separate groups of students designed and fabricated simple prosthetic devices so they could attach items such as a jump rope handle or a hockey stick. Their motivation was to give this particular student the opportunity to be part of more activities.

As a group, we did research to learn about the internal structure of the human hand, the number and arrangement of the bones, ligaments, muscles and other connective tissues. We also researched and learned about the mechanics of a human hand and using the engineering design process, students learned and practiced how to revise and modify their designs to reach a working model using readily available materials.

Using the National Aeronautics and Space Administration's (NASA) Bionic Hand Program, we used cardboard, string, straws, rubber bands and tape to fabricate several prototypes. Although these prototypes are not sturdy enough to hold much weight, they gave us an idea of how the hand works. Based on their observations, students generated ideas and plans for modifications and enhancements on subsequent prototypes. Some of their ideas included hand transplant, sophisticated robotic hand, and even getting a hand from a cadaver. After discussing our ability to do some of these ideas, I gently guided them towards a more appropriate and achievable 3D printed prosthetic device.

The final model was fabricated using a 3D printer. Using the 3D printer allowed the students to apply their knowledge of mathematics. They had to measure to get the correct size and make adjustments as needed. Rotating objects on the computer screen to get a better view of models require them to use angle measurement within the 3D printer's software, and they used their communication skills to present their final model at the school and the district's science fair.

These multi-week inquiries allow students to explore, in depth, all the disciplines of STEM and provide opportunities for them to expand their understanding of each discipline and how they can be integrated to find different solutions to real-world problems.

Instrumentation

A 10-question attitudinal survey, developed by the author, was administered at the beginning of the program to stablish a baseline of how students gauged their own strengths and interests, presently and in the future, in math and science. The same survey was done at the end of the program to compare how students' attitudes had changed and to get a glimpse of how students saw themselves after participating in this type of project based, hands-on STEM program. The possible choices to each of the questions were coded on a scale from 1 (Strongly Disagree) to 5 (Strongly agree).

The following is the list of items from which students had to select as to how they felt or saw themselves now and in the future. The same questions were given to the students before the beginning of the program as well as at the end of the program.

A: I would consider choosing a career that uses math.
B: I could do advanced work in math.
C: I will need science for my future work.
D: I am sure I could do advanced work in science.
E: If I learn engineering, then I can improve things that people use every day.
F: Designing products or structures will be important for my future work.
G: I believe I can be successful in a career in engineering.
H: I am confident I can produce high quality work.
I: I am confident I can make changes when things do not go as planned.
J: I am confident I can set my own learning goals.

Data Analysis

To ascertain how students viewed themselves and how their self-views changed after their participation in the after-school STEM program, we run a simple descriptive statistical comparison of their responses to the 10-question attitudinal survey. The sample size in the pre-survey was N=242 in the pre-survey and N=180 in the post-survey.

Results

In the following tables, the number in parenthesis indicates the level of agreement or disagreement to that specific question. The capital letters (A through J) at the top of each table represent the 10 questions from the list mentioned above.

Results of Attitudinal Survey Before Participation in Program

Table 1 shows the number of students' response as to whether they agree or disagree with each of the statements from the chart above (numbers in parenthesis) before the beginning of the program. The capital letters at the top of the table (A though J) refer to the list of 10 questions described above. As the numbers show, students across the district see themselves being able to do well in math and science classes. Furthermore, most see themselves as future mathematicians and scientists.

The following table is the conversion from the number of students selecting that response to the percentage of responses to each of the 10 different questions. This conversion was done to allow for comparison of responses from the attitudinal survey before participation in the program. Tables 1 and 2 are based on the responses of 242 students.

Table 1
Attitudinal Survey Responses Before Participation in Program

Score	A	B	C	D	E	F	G	H	I	J
(5)	62	63	78	62	76	52	55	95	85	129
(4)	91	119	78	104	112	97	85	97	123	96
(3)	60	38	55	48	39	56	68	36	21	14
(2)	20	17	24	20	13	29	26	13	12	2
(1)	9	5	7	8	2	8	8	1	1	1

Table 2
Conversion from Number of Responses to Percent in Attitudinal Survey

Score	A	B	C	D	E	F	G	H	I	J
(5)	25	26	32	25.6	31.4	21.4	22.7	39.2	35	53.3
(4)	37	49	35	43	46	40	35	40	50.8	39.6
(3)	25	15.7	22.7	20	16	23	28	14.8	8.6	5.7
(2)	8	17	10	8	5.3	12	10.7	5.3	4.9	0.8
(1)	3.7	2	3	3	0.8	3	3	0.4	0.4	0.4

It is worth mentioning that the students participating in this program are highly motivated and most are classified as gifted or highly gifted. However, as the data shows, even within these groups many students feel or think they might not be able to do well in the fields of mathematics and science. Whether these students go into the STEM fields or not is beyond the scope of this study as we would need a series of longitudinal studies.

Results of Attitudinal Survey After Participation in Program

Table 3 shows the number of students and the level of students' agreement to each of the 10 categories after their participation in the STEM program. The change in the number of students taking the survey was due to teachers admitting and releasing students from the program and attrition. In an effort to maintain consistency, students' IDs were matched and from the 242 original students that took the surveys previous to the start of the program. 180 students stayed in the program from beginning to end and took the post survey at the conclusion of the program.

As Table 3 indicates, responses are still higher in the agree and strongly agree categories from the beginning of the program. These results tell us that the students' participation in the STEM program had a positive effect on their attitude and prove to them, and to their teachers, that they are capable of doing high caliber work in mathematics, science, engineering and technology.

Table 3
Attitudinal Survey Responses After Participation in Program

Score	A	B	C	D	E	F	G	H	I	J
(5)	51	64	50	44	83	54	52	86	87	108
(4)	66	71	56	74	67	54	57	71	72	55
(3)	48	36	53	41	23	47	48	18	19	12
(2)	13	6	18	17	5	18	12	4	2	4
(1)	2	3	3	4	2	7	11	1	0	1

Table 4 is the conversion to a percentage of students selecting that response to each of the 10 different questions. A comparison of the pre and post (table 2 and table 4) tables shows that at the end of the program the number of students' responses were somewhat more uniformly distributed. More importantly, it shows a decrease in the number of students that disagree as to whether they can do advance work in math or science and would consider careers in these fields later in their educational careers.

Table 4
Conversion from Number of Responses to Percent

Score	A	B	C	D	E	F	G	H	I	J
(5)	28.3	35.5	28	24	46	30	29	47.7	48	60
(4)	36.6	40	31	41	37	30	31.6	40	40	30.5
(3)	26.6	20	29	22.7	12.7	26	26.6	10	10.5	6.6
(2)	7.2	3.3	10	0.9	2.7	10	6.6	2.2	1.1	2.2
(1)	1.1	1.6	1.6	2.2	1.1	3.8	6	0.5	0	0.5

The Change in Percentage of Questions Between Pre- and Post-Survey

Analysis of a cross section of the results shows a slight positive change towards STEM in attitude from pre-participation to the end of the program, question items A, D and G.

Table 5 shows the change in percentage of students that would consider a career that uses mathematics (A). There is a slight decrease in the number of students that disagree with the statement and a positive increase to students that would choose a career that involves math.

Students' initial response as to whether they can do advanced work in science (D), most were positive they could do it. However, data in table 6 provides an interesting change in students' views. Both end of the scale changed with less students agreeing and disagreeing to whether they see themselves being able to do advanced work in science. There was an increase in the neutral column.

Table 5
Percent of Students That Might Choose a Career in Math

Score	Pre (A)	Post
(5)	25	28.3
(4)	37	36.6
(3)	25	26.6
(2)	8	7.2
(1)	3.7	1.1

Table 6
Percentage of Students Doing Advance Science Work

Score	Pre (A)	Post
(5)	25.6	24
(4)	43	41
(3)	20	22.7
(2)	8	0.9
(1)	3	2.2

We see this as a positive change since there are less students that see themselves as **not** being able to do advanced work in science. However, there is also a decrease in the number of students that think they can do advanced work in science. The fact is that these students are very capable of doing advanced work in science, but as mentioned earlier, for many students this is the first time participating in hands-on science activities. What this tells us is that their previous science instruction was not as in depth or as involved as during the afterschool STEM program and they now see that they have to work a little more. More importantly, they learned that they have to analyze, do problem solving, and apply critical thinking skills as their projects progress.

We observed similar results while comparing students' response as to whether they believe they can have a successful career in engineering, question G on the list of questions. Table 7 shows a comparison of the pre and post STEM program responses to this question.

As we saw in most of our comparisons, students were able to succeed working with an integrated curriculum. They seem to like the system not because they are strong in all fields but because they are able to see the connections between the subjects and their application to real life situations. Students are also able to work collaboratively with others that complement their strengths as well as their weaknesses.

Table 7
Percentage of Students That Believe They Can Have a Successful Career in Engineering

Score	Pre (A)	Post
(5)	22.7	29
(4)	35	31.6
(3)	28	26.6
(2)	10.7	6.6
(1)	3	6

Discussion

Jackson (1997) stated that students in most classrooms are not actively engaged in their learning. He argued that this occurs because students sit in classrooms "void of excitement…discourse and learning" (p.5). Chase-Lockwood and Masino (2002) agreed with Jackson and added that one of the main underlying causes for student failure to learn is ineffective teaching instruction. There is a disconnect in the teaching of the subjects and an emphasis on skills and memorization (Baker & Galanti, 2017).

As the arguments presented in this brief study suggest, an integrated curriculum implies a holistic approach (Colwell, 2008; Russell & Zembylas, 2007) and creates an environment where students actively create links between their previous and their new knowledge (An, Kulm & Ma, 2008; Duatepe-Paksu & Ubuz, 2009) not by merely memorizing the contents and concepts but by "making sense of them through assimilation and accommodation" (Duatepe-Paksu & Ubuz, 2009, p.272).

Gebhard, Hafner and Wright (2004) compellingly stated that educators must implement changes in their "instructional practices…to support students in owning the language of math" (p.46) by teaching explicitly and meaningfully so that students can apply their newfound knowledge to real life situations.

The introduction of new approaches and strategies in the implementation and application of STEM education will benefit all students. Especially beneficial to the English language learners and students with learning difficulties since engagement and exploration with physical models will enhance students' learning. One of the key learning outcomes is to learn how to problem solve in cooperative groups by applying the science and engineering principles to social issues.

Engagement and motivation are important factors while working with most students but specially students with learning difficulties. Without engaging lessons and activities, students lose their interest in the material. When students are not actively involved in the lesson, they are more likely to engage in disruptive behaviors, which affect their own learning as well as the learning opportunities of the entire class. One of the main goals of this study is to show that STEM activities and programs increase students' understanding and engagement. In addition, we are able to introduce them to new areas of study and show them future career choices.

These are positive changes in the students' confidence and attitude toward learning in general. These positive outcomes will be the learning foundation for the whole community. As teachers, it is our responsibility to provide students with sufficient opportunities for them to explore and learn so that we may assist them in their effort to make sense of their environment through varied and meaningful learning opportunities.

Conclusion

This study explored how an integrated STEM program produced and fosters students' creativity as well as positive changes in students' attitudes towards math, science and learning in general. Increasingly diverse classrooms create difficulties for educators in maintaining students' attention. In response, teachers are relying on alternative strategies to make learning materials more relevant to students in ways that will have a positive impact and be the learning foundation for the entire learning community. As teachers, it is our responsibility to design and implement a variety of meaningful lessons and activities that will provide students with sufficient opportunities to explore and learn so that they make sense of their environment.

What many studies neglect to mention is that, in reality, students do not have a defined idea of what a career in math or science means. Unfortunately, for most students, science is something they see in a book or a video a few times a week or a few weeks out of the semester. They may never meet someone with a career in math or in science. It is of the outmost importance to bring professionals into the classrooms. Coordinating a Career Day is a great way expose young students to these professions and to involve the community members. The Visiting Scientist program is another opportunity to showcase careers that students do not know are available to them. We must make learning real and make it come alive and avoid watering down the content in the name of STEM integration. It is imperative that we provide students with engaging hands-on STEM experiences to increase their interest in STEM-related fields (Baker & Galanti, 2017).

As this brief study shows, we must teach them the human side of math and science, the importance of not only learning but applying math and science to social issues. We must show them how the sciences connect us all. We must show students how mathematics, the arts and science can help them generate a multitude of options and solutions. Analysis of the students' choices before and after the program show several benefits. We see an increase in their understanding of the different areas of STEM as well as their general level of engagement in school. More importantly, students demonstrate an increase in their awareness as to the effort necessary to do well in these areas now and in the future. As this brief study demonstrates, we cannot change how students view and identify themselves if we do not provide them with real life examples; real people with careers in mathematics and the sciences, as well as different kinds of artists. We must give them the most powerful transformative tool we have. We must help them develop and internalize the healing power of creativity.

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