Make it happen: A study of a novel teaching style, *STEM Students on the Stage* (SOS) ™, for increasing students' STEM knowledge and interest

Abstract. STEM education has become strategically important to increase college readiness of high school graduates in mathematics and science, cultivate STEM interest in students, boost STEM majoring students, and prepare students for 21st century workforce. The purpose of this study is to investigate a new STEM Project-based learning model developed by Harmony Public Schools (HPS). We used theoretical sampling and 11 students (5 seniors, 5 juniors, and 1 sophomore) were interviewed. Interview transcripts were analyzed by using grounded theory coding and constant comparative analysis. As a result of the analysis, a new STEM education model named the *STEM Students on the Stage (S.O.S. ™)* was emerged and defined. The emerging substantive theory suggests that through the STEM S.O.S. model, students increased their conceptual understanding, STEM interest, and research interest in higher education and developed self-confidence, and skills in technology, life and career, communication and collaboration and these skills continued to improve circularly. Findings were discussed in the context of STEM education and its effects on students' interest in STEM careers.

Keyword: Harmony Public Schools, STEM, S.O.S., 21st century skills.

Introduction

Science, technology, engineering, and mathematics (STEM) education has become a critical priority for countries in the last decade due its strategic role in the country's global competitiveness (Sahin, Ayar, & Adiguzel, 2014; Sahin, 2013). Myriad reports have highlighted the linkages between a well-rounded K-12 STEM education—to prepare the next generation's scientists, leaders, and innovators—and countries' economic leadership (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007; President's Council of Advisors on Science and Technology, 2010). Research has also indicated that STEM jobs pay higher salaries and provide more job opportunities than other professions (Terrell, 2007). U. S. Department of Labor announced that more than 1.2 million STEM employees will be needed by 2018; however data shows that there is a shortage in meeting the need in terms of numbers and quality (Lacey & Wright, 2009). Therefore, providing STEM education in a way that it will not only teach the content but also cultivate STEM interest becomes strategically important and student attitudes toward STEM education proved to be an important contributor to increase student participation in STEM subjects (Mahoney, 2010).

For this purpose, different approaches have been pursued to teach STEM education in K-12 settings. Some of the research-based methods to interdisciplinary STEM education are Design-Based Science (DBS) (Fortus, Krajcikb, Dershimerb, Marx, & Mamlok- Naamand, 2005), Math Out of the Box™ (Diaz & King, 2007), Learning by Design™ (LBD) (Kolodner, et al., 2003), Integrated Mathematics, Science, and Technology (IMaST) (Satchwell & Loepp, 2002) all of which incorporate a course of inquiry-based learning that encourages students to complete a project with respect to existing knowledge and experience, and to present what they learned and developed as a result (Laboy-Rush, 2011). Mostly, each method provides students a four- or five-step process, with each step accomplishing a specific process-based objective. Similarly, the project-based learning strategy has been found and proven to be effective STEM education program (Laboy-Rush, 2011). The reasons of why these methods are implemented are thanks to the models' integration of cooperative learning to work in teams to do research, test theories, and produce artifacts (Meyrick, 2011). Harwood and Rudnistsky (2005) indicated that such teaching and learning methods increase students' involvement and engagement, and "can stimulate students as well as enable them to recognize links between their lessons and tasks performed by engineers in the real world" (p. 54). In this study, we investigate a new model that incorporates components of several active learning strategies including project-based learning and inquiry-based learning.

STEM Teaching in the U.S. and The Novel Teaching Style, STEM Students on The Stage (S.O.S.™)

U.S public education has some chronic problems including lack of college readiness of high school graduates in mathematics and science (Diaz & King, 2007), lagging behind on international tests (e.g., TIMSS, PISA). Also, there is a shortage in STEM majoring professionals (NRC, 2011; Schmidt, 2011) and high school graduates are not prepared well for the 21st century workforce (NRC, 2011). To address these problems, integrated STEM education or Project-based learning has been utilized (e.g., Fortus, Krajcikb, Dershimerb, Marx, & Mamlok-Naamand, 2005) based on research showing that projects can increase student interest in STEM by solving authentic problems, collaborating with others, and building products that have real life connections and applications (Fortus, Krajcikb, Dershimerb, Marx, & Mamlok-Naamand, 2005). Similarly, Harmony Public Schools (HPS) have developed their own STEM curriculum that incorporated project-based and inquiry-based learning titled "STEM Students on the Stage (S.O.S ^{TM})" with the Race to the Top grant funded by U.S. Department of Education with the goal of not only increasing students' STEM knowledge and interest but also to producing self-motivated and self-regulated learners (Harmony STEM Program, 2013).

According to Harmony STEM Program Handbook (2013), STEM S.O.S. aims "to maintain the focus on standards-based and student-centered teaching while enriching and extending the learning of students through PBL projects. The goal is to promote not only collaborative skills and student ownership of learning but also to promote student success in state and national standards" (p.x) through student projects; Level I, II, and III. According to the curriculum, all students have to complete level I project following with either regular level II or advanced level III project.

Level I. Students are assigned two level I projects per semester on each core subject (Mathematics, Science, ELA, and Social Studies). Projects are conducted in class with a group of 3-4 students aligned with the curriculum's scope and sequence within a week. Students are provided training and necessary documentation to complete the project at the beginning of the school year. Teachers provide timely guidance and feedback for completion of the projects. The final product consists of a report of their work with a digital presentation of the project. Core content teachers conduct assessments using related rubrics for each project separately.

Level II. Apart from level I project, students are required to complete one interdisciplinary STEM S.O.S. project either from mathematics or science. Social studies and ELA components have to be part of those projects. Projects are assigned at the beginning of the year out of 25-30 mathematics and science projects. These are year-long projects. Teachers provide timely guidance, feedback, and documentation including rubrics for the successful completion of the projects. Upon completion, students present their findings and products through video presentation and website.

Level III: Level III projects are for students who enjoy the challenge of creating and conducting their own research and product. These projects are interdisciplinary and integrate the use of technology in each and every step of project completion. The contents are rigorous and deserve extra credits upon completion. Projects have to be completed by using given materials within certain time constraints. The project's scope, driving questions, expectations, and guidelines including materials are decided together with teachers. Student level II and III projects are presented at the campus-wide STEM festivals, science fairs, STEM Expo exhibitions, and STEM related competitions.

The purpose of this study was to investigate and find out components of a successful STEM engagement case in a high school, in which students take responsibility of their learning and develop better understanding of science, technology, engineering, and mathematics education and develop some important skills that are pivotal in the 21st century workforce. The overarching research question we sought answer to was:

> How does learning in the STEM Students on the Stage (SOS) learning model occur and what benefits do the students gain in the end?

Method

Settings:

Harmony Public Schools, a network of high-performing K-12 public charter schools across Texas including all metropolitan areas focuses on providing science, computer technologies, engineering, and math education (STEM) to traditionally underserved students (HPS, 2014). HPS schools serve more than 24,000 students of diverse groups: 56% receive free or reduced price lunch and 80%+ are nonwhite (45% Hispanic, 19% African American, and 16% Asian).

Participants

The sample was collected from one of the Harmony high schools in the Houston area. Eleven students agreed to participate in the study. Out of 11 students, 5 seniors, 5 juniors, and 1 sophomore students were interviewed. The 11 students were taking one of the following courses; Pre-AP Physics, Chemistry, or AP Physics. Three different teachers taught the courses.

Procedure

A broad research question was formulated as how learning in the STEM Students on the Stage (SOS) learning model occurs and what benefits students gain in the end. The questions were addressed by a grounded theory study as method of analysis to explore the novel teaching style in a multi-school charter system high school and to develop a substantive theory in this regard.

We regard grounded theory methods as a set of flexible analytical procedures that inspires researchers to remain close to their studied world. In addition, to synthesize and indicate processual relationships, the need for developing an integrated set of theoretical concepts helps us esteem grounded theory methods (Charmaz, 2010). We recognize our position within the studied world, locating ourselves within our research interest in codifying the STEM S.O.S. model and disclosing student gains through the model.

Samples were collected from one of the Harmony Public Schools where STEM S.O.S model was implemented as a pilot study during May of 2012-2013 school year. The model was officially launched in all HPS campuses recently in 2013-2014 school year. The sample was identified during an iterative process over a two-semester period, based on the interaction of data collection and analysis enabled via theoretical sampling throughout the study (Holt & Tamminen, 2010). We reached theoretical saturation with 11 individual interviews (out of 15). We had to remove those 4 interviews from the data for not contributing to advance theoretical saturation. Theoretical sampling was utilized in the present study, which was grounded on emerging concepts and associated with figuring out new people, to advance or refine theoretical saturation – not merely to fill in gaps in the data (Charmaz 2005). The students, who enrolled in the program and were interviewed, were all volunteers and consented.

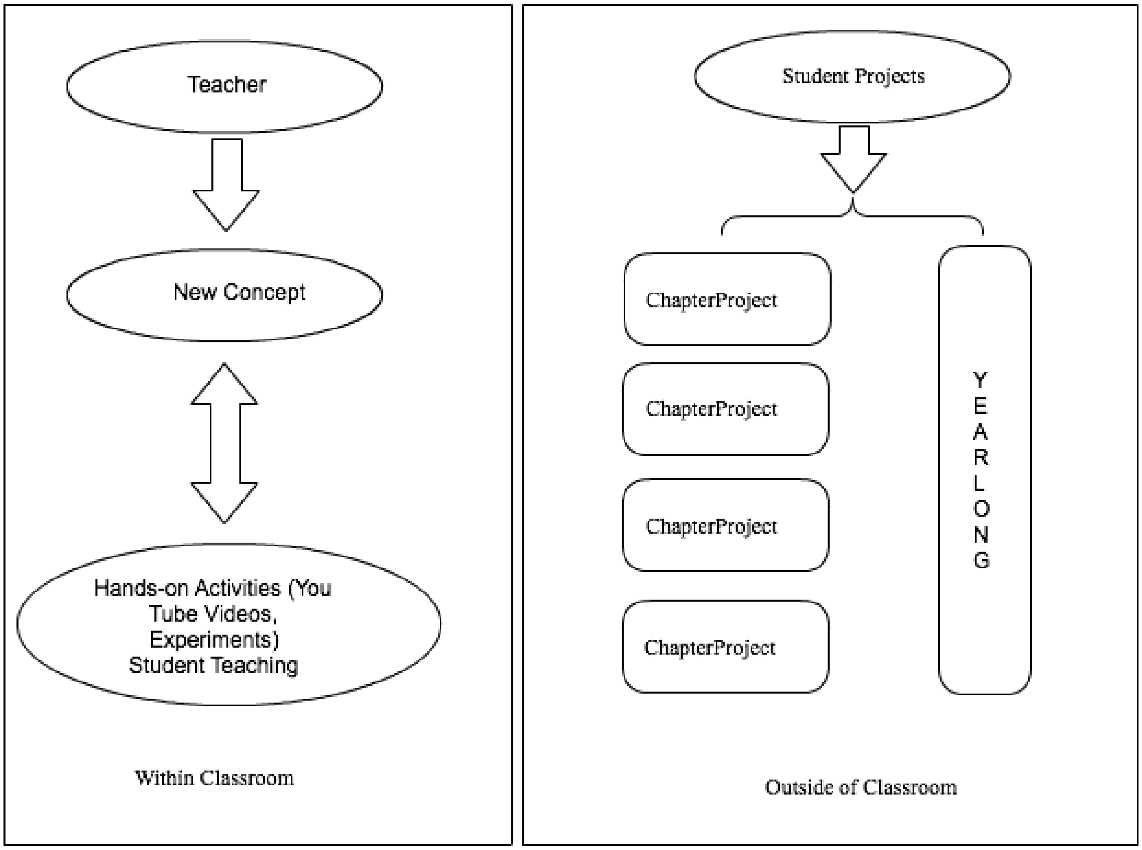
For the analysis of the data, we followed the grounded theory coding and constant comparative analysis. Initially, each student interview was open-coded using action codes (Charmaz 2010). Then, we applied focused coding through constantly comparing each initial code with similar ones in order to develop categories and sub-categories from the raw data. Whilst the categories were being produced, we performed axial coding through relating categories, via the combination of inductive and deductive thinking. We present a series of diagrams that illustrate the relationships among categories during these coding processes. The analytical process provided the emerging substantive theory of the model and student gains of the STEM S.O.S. model.

Results

The findings, discussed in the subsequent sections, revealed two core categories such as (1) STEM S.O.S model (see Figure 1) and (2) Impact on student gains (see Figure 2).

Figure 1

How STEM S.O.S Model Happens from Students' Interviews



To the students, STEM S.O.S model has two critical parts: (1.a) Teacher-directed teaching or Teacher lecture and (1.b). Student Projects. Later, student responses showed that teacher lecture part has three important components: (1.a.a) Lecturing or teaching the theory part, (1.a.b) Hands-on activities part, and (1.a.c) Student teaching part. In addition, the interviews exposed that two fundamental student gains, (2.a) Academic and (2.b) 21st century skills, were functions of the novel teaching style, STEM S.O.S. Furthermore, the first student gain has three sub-categories: (2.a.a) STEM interest, (2.a.b) Knowledge, and (2.a.c) Research interest in higher education, and the second student gain has five sub-categories: (2.b.a) Self-confidence, (2.b.b) Technology Skills (2.b.c) Life and Career Skills, (2.b.d) Communication Skills and (2.b.e) Collaboration Skills

1. S.O.S model

1.a Teacher-directed teaching

1a.a Lecturing part. Teachers in S.O.S model start a new lesson by lecturing about a new concept to lay foundation for upcoming parts as student 1 stated "…Initial lecture, he introduces the ideas, he introduces the chapter or whatever the subject area is." This part includes direct lecturing of the concept as well as asking questions to students and observing if there is any part that students seem lost as indicated by student 4.

> One of the things that I see out of him (Science Teacher) is he is not just standing behind at lecture podium [and] talking. He is teaching, he is interacting with the student. He is making them laugh. He is making them understand things. He doesn't just talk to you like most teachers do. He does a great job.

This part is different than average lecturing because the teacher is not only lecturing but also actively watching students' gestures and answers to his questions to make sure everybody understands as student 10 emphasized:

> Well, during lectures I can tell Mr S. talks to us like one-on-one, usually as a group, usually to my little group and other little group(s). He comes to each group like every ten minutes like checks out if we have any questions or incorrectness like he goes next through (Student 10).

Also, teachers don't do just lecturing but also explains any formula or theory step by step and/or with an example from daily life with hands-on experiments or videos.

> His lecture, the way he teaches good because instead of making you memorize things, he shows you how every things are connected, he shows us how every laws connected to one another (Student 10).

Moreover, one of the important parts of this section is giving students many opportunities to be involved in. This part is enriched with several different activities including hands-on experiments, You Tube videos, and student teaching.

> Except when he is doing the initial lecture, he doesn't do much talking which is good. Initial lecture, he introduces the ideas, he introduces the chapter or whatever the subject

> area is. Then we have videos, we have demos, we have student teaching, student all the time. He does do talking in the class. He is not just sitting on the desk behind the class. He is very proactively working to make sure that we learn the material (Student 4).

***1.a.b. Hands-on activities*.** This part is central to the teacher's lecturing or teaching part. This makes lecturing part very engaging and results in an increase in student involvement. Student 9 described very clearly the benefits of the S.O.S in terms of students' involvement as "[S.O.S.] teaching is very hands on and the teacher wants like YouTube like physics he doesn't just us to know physics so he puts the effort to make it more fun and enjoyable. It is mostly the hands on aspect of it, most of other teachers [in other Physics classes], they just want lectures and it just you can't spend so much time just paying attention, you dropped off, but with the hands on you stay on topic."

In this part, teachers incorporate experiments, YouTube videos, and different hands-on activities to explain the theory and show the relevancy of the content with real life, thus learning sticks to students' minds as student 2 put "I presented in school [festival and classroom] we presented in the STEM expo, and ISWEEEP, and repeating it so many time really helps to stick you in your head" (Student 2).

***1.a.c. Student teaching*.** The last part of the teacher-directed lecturing part is students' teaching. How this works is teachers assign projects to a student or group of students for each chapter before they start teaching about the content. Teacher asks the related group of students to teach and do the experiment that explains the content or concept as one student indicated " So if we learn about… suppose we need to learn sound waves that is what my demonstration is about and the teacher allows us as students who come in and if we have demonstration that has to do with the subject. We come and we do it in front of the whole class. … like the Bernoulli principle or anything else" (Student 2). Student 4 also focused on one of the benefits of student teaching that enables them to learn the content instead of memorizing for the exams or tests:

> Let's say he makes us doing experiment like a roller-coaster back there and after we completed, after he teaches us, how to construct it, how all the formulas work, then he says pick a day on this calendar. So, okay that day. You are going to teach to the class that day. Teach what? Everything you just learned. Instead of regurgitating, you are actually going to take what you have learned and understood from what you built or what you made and teach people about it.

Therefore, students act like a teacher and this helps both student teachers and other students to learn the content and benefit in different ways including increasing self-confidence, knowledge, and developing positive attitude towards science subjects.

1.b. Student Projects

Student projects are two types and have two goals: First type of projects are given during each chapter as mentioned in the previous section. Students are provided a short-term project that is related to the content they learn during each chapter. A student or group of students is assigned to prepare an experiment including hands-on activities, experiments, and/or video. Part of their responsibility is to present their experiment while related content is being taught. The second type of project is a yearlong project. Students choose those projects among a list of projects that are posted at Harmony Schools' Physics webpage at the beginning of the year: "… I mean at the beginning of the year there was a list and I randomly chose but I ended up liking it a lot because it is more interactive and I am an interactive person. So it went with me and I wouldn't have changed it or I am pretty sure even if I looked inside of each one, I would have picked this one" (Student 3). Students are required to prepare a video presentation including picture of each material used during completion of the project, sets of short video episodes of experiments, related graphs, tables, and conclusions. Student 3 put this as “we make science videos. And we take videos of the experiment like little experiments and record them here or anywhere. And then once we put it together, we put it together as a video. Would you like to see a sample?” As their teachers check students’ products and provide feedback, students go and fix the parts they got feedback about “We basically… we have to go home and then fix them up. And put them together and this is what…” (Student 3). Students showed ownership for the projects they chose because they study and try to complete the projects regardless of place and time, including after school hours, weekends, and homes. Student 3 continued to explain how they work to complete the projects they picked “After school [hours], but mostly after school and then whoever we divide up the work, so if someone takes a video we go home and edit it or just like that.”

They are also required to upload the video they make to the Harmony You Tube Channel as well as a brochure explaining everything about the project they complete. Another requirement is to create and design their own website that they can present everything they do during completion of the project. This yearlong project is usually an individual project that pushes students to collaborate with other students to complete it. Students find many opportunities to present or show their science demos before an audience. For example, whenever their school has a visitor like congressman, mayor, or educators from other institutions, students display their demos. Students also present their findings and products during STEM EXPO and ISWEEEP competitions. Science demos change students’ way of looking at science. With all these activities and projects, students develop a sound science understanding and science is perceived as less scary or as the least favorite subject, as student 2 expressed:

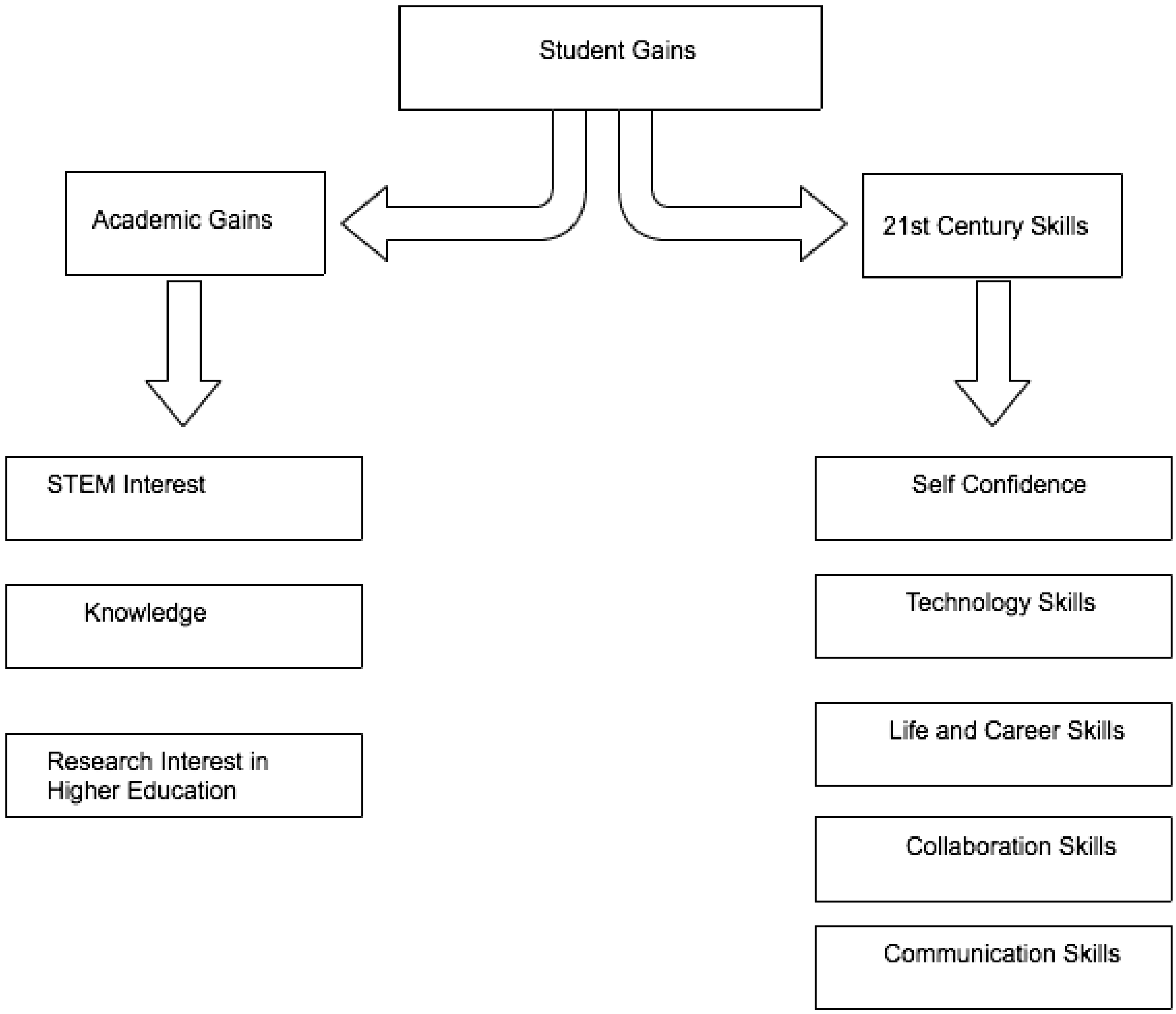
…I said science was not always my biggest thing, but being in demos let you know that it is just not listening and drawing or writing down your equations or writing down the words that the teacher said you can get hands on you can figure out something and you can learn about it and apply it to everyday. And it is one of those things that like you see on TV or you see someone else to do and you are like wait a minute. It is not magic or it is not like who comes up with this stuff, it is all basically science, it is Physics, it is Chemistry, it is any of those things.

(2) Impact on student gains

The second core category is the impact on student gains, which encapsulated students' both academic and 21^{st} century skills. Student provided deep information about their gains during the interviews. The information provided over the interview questions about student gains revealed two categories, academic and 21^{st} century skills (see Figure 2).

Figure 2

Student Gains from Student Interviews



2.a Academic

In this category, students stated the important role of the STEM S.O.S on their academic skills development. The student 5's following expression "I think I developed how to study the right way. Like how to learn, how to approach the problem and then how to apply it in real life" clearly illustrated that the student started to recognize how to conduct academic research. Students became aware of the connections between the academic knowledge and its applications in real life. "You can apply to many things and whatever you do in the future hopefully … you learn how to apply to it" student 2 stated. Student 4 also said, "…so in real world environment with me, it helped me developing something very useful". This category leaded us to three sub-categories, STEM interest, knowledge, and research interest in higher education.

2.a.a. STEM interest

Student answers revealed that they developed STEM interest through the STEM S.O.S. Model. In this sub-category, students' responses showed that they started enjoying scientific experiments because they felt that it became fun for them. Student 2 stated it explicitly:

> …I was like ooo this is fun. It is like you know cute and can come up with ideas even think I can bring someone and change the color and … it when with the carbon dioxide hand in the air it fades away so it was really cool.

Another student also indicated developing STEM interest through a STEM S.O.S model teaching by saying, "Science demo are like realizes like one of those, it is fun, you learned it and it is not so hard that you know you stressing about it".

They usually expressed that they were not used to be good at science but became really into it. Student 3 said, "I have never really been great in science, but I have learned that when you really focus on it, you add interest". In addition, student 2 expressed the interest clearly:

> I always like I said science was not always my biggest thing, but being in demos (student projects) let you know that it is just not listening and drawing or writing down your equations or writing down the words that the teacher said you can get hands on you can figure out something and you can learn about it and apply it to everyday.

2.a.b. Knowledge/Conceptual Understanding

Students all agree upon that they learned a lot in this teaching style. Students felt that they increased their conceptual understanding of the science concept taught through participating, building their demos, and conducting experiments, etc. "Yes, I will never forget that principle because I have learned it, I saw it, I experienced it. It will stay with me forever" said by student 11 which showed how lifelong learning happens through the STEM S.O.S. Model. The second student underscored the importance of visuality of the STEM S.O.S, on their understanding concepts by stating, “So visual learning and letting you know what it is all about it helps to understand everything about it”. The STEM S.O.S also not only helps students learn the content but also helps them how to adjust knowledge or difficult topics according to their audiences and increase their knowledge conceptually. Student 3 explicated, “I am also definitely learning how to simplify physics for myself and for other people to make it easier for them to understand because if I simplify it for them, I’ll be learning too”. The student 2 also stressed to what extent they learn during the class with the following expression:

> So it is just in the class you learn more, you get to know how to calculate things kind of stuff. And in the Physics demo it is little heads up that you will learn a little bit of it and that way you just like oh yeah I remember this I know this.

The student 4’s expression also illustrated their confidence on the increase of their academic knowledge and conceptual understanding: “Instead of regurgitating, you are actually going to take what you have learned and understood from what you built or what you made and teach people about it”.

Students also explained that they became learners of the things happening around them. The S.O.S helped them pay attention to their environment and mull over the physical things occurring in their daily lives. Student 3 stated it very well, “You learn what happens. You never realize it, you know when the car moves there is something you are learning what is happening beneath the wheels and it is interesting to learn that”.

2.a.c. Research interest in higher education. The last sub-category of the impact of academic gains is research interest in higher education. In this category, students illustrated their tendency to continue conducting research in higher education. Student 6 stated this interest obviously as follows:

> I guess definitely it helps you to be able to gain a group of friends who have the same interests as you. Like when you go to college and you find a study group like it’s really

> nice. I feel like after doing this I feel like you know when you find somebody who has the same interests as you, we're all here doing this then you'll go study with them.

As mentioned in the previous sub-category, students believed that they learned a lot. In this category, they also showed their plans to continue applying their information in higher education. Student 7 showed this desire by saying, "hopefully I can carry all those skills over not only to higher education, but also to college, graduate school and my career". Student 10 also expressed his research comfort as follows, "I feel more comfortable like I can already do [research] by myself with other students, I can create study groups and always feel like teacher kind I like having back and forth communication like really helps you".

2.b 21st Century Skills

Apart from academic gains, the findings also showed the impact of the STEM S.O.S. model on students' social and emotional gains. Students started to feel that they could achieve something such as presenting in front of people, communicating with other students well, understanding the benefits in daily life, etc. Generally, students focused on five sub-categories of the category of impact on 21st century skills gains such as self-confidence, technology skills, life and career skills, communication skills, and collaboration skills.

2.b.a. Self-confidence

In this sub-category, students explained that before they were taught with the STEM S.O.S. model, they were not used to do things like preparing a presentation, presenting it before a crowded group and communicating with people, etc. After exposure to the model and completing the projects as part of the teaching; students'confidence on teaching and presenting increased. Student 2 described it as "You know it feels nice to know something and it gives you confidence and you feel like wow I know this so being a little quite". The same student expressed the feelings as follows, "…able to present better, get over the fear, I didn't know how to speak in public. I have already had experiences of speaking in public and this just encourages me and improve that ability more".

Through help of STEM S.O.S., students who were nervous about their social abilities improved their skills. The student 1 stated it appreciatively:

> …I mean being able to talk like first being nervous like we had this one thing called news testing… They had like cameras, were recording us you know being nervous in front of people I was like I don't know how do I look like in the camera you know stuff like that. So I mean being able to speak in front of them, be able to relate what I have to say.

Students also believed that they needed confidence and better communication skills for higher education, and felt the STEM S.O.S helped them achieve that. Student 6's expression illustrated the belief explicitly:

> …and in a way built my confidence because I'm okay with speaking to a crowd of people as long as I know what I'm speaking about, I'm okay with speaking to them. And it really helped me because I know that in order to go into the medical field you have to bring more to the table, you can't just like go to college and be like oh okay I want to study this, you know you have to be determined and confident in what you're doing. And I feel like it really built my confidence up and helped me to study because until this day, if I don't understand the teacher, like if I don't understand her I'll still go home and I'll study myself and I'll get it. And I'll come to school.

2.b.b. Technology Skills

As a result of being required to make YouTube videos, websites, video presentations, students also developed their technology skills through the STEM S.O.S model. Many of the students did not know how to deal with technological tools before the STEM S.O.S., as student 2 described "Making your web sites you need to learn how to go and then. On this I learned from someone how to link a picture. So I didn't know how to do that."

"When I go home, I am usually working on editing this videos and putting them together" said by student 3, illustrates that students are dealing with the technological tools not only in their school but also at their homes. Because almost each and every step of project completion is done by using technology, students began to develop variety of technology skills. The student 9 stated that, “I developed how to build website, I learned how to do that because I didn’t know before”.

Even though student 4 had already worked as an intern for a technology company, the STEM S.O.S was also helpful for the student. Student 4 said this explicitly:

> Even though I have prior knowledge in these things, I literally… my test subjects worth to this class. So I did a video whenever I had to create a website I took my knowledge that I am gaining in Apple and different sources and from here, putting them all together and literally testing them out right here, which is extremely great because then I don’t have to worry about this in another project work for another company.

2.b.c. Life and Career Skills

Quite significantly, students became aware of what is going on in real life. This helped them look at the world in a scientific way and discover things that might assist them in their lives and careers. Student 5 showed this truth by stating, “this helps you learn from and it helps in your real life, for example, in a kitchen or while driving”. They learned how to manage things through the STEM S.O.S as student 7 said:

> In my daily life the management skills [I gained by completing science demos on the due date] has helped a lot. I am able to better manage, I think, that kind helped with the college applications a lot and I guess in general I am just able to manage my time wisely.

Students also focused on helping others in real life such as people who are poor, unhealthy, needy, etc. This obviously shows the extent they became aware of the benefits they could provide through what they learnt during the class, after school hours, and STEM EXPOs not only for themselves but also for others. Student 1 expressed it emotionally:

> … since I want to mainly to go into social work, I want to go to families and homeless people so I can notice different things about know whether a child has been abused or the homeless man is also doing you know illegal s.. or not. Noticing different things like that about the person, individual make sure whether they are healthy or not. And making sure that verbal saying wherever is going on matches their parents.

Another student even started considering passing the skills and knowledge they gained via the STEM S.O.S model to their children and said, "It is always nice to know so I can always teach to my children". Quite clearly, students believed that the things they learned through the STEM S.O.S can facilitate their personal and career lives.

2.b.d. Communication skills

As seen from the previous categories, students acquired several skills in different fields such as content knowledge, self-confidence, social skills, etc. Many students underscored the importance of the STEM S.O.S class environment by comparing those with their other classes. Student 4 made this comparison through the communication environment as follows:

> When the other teacher is speaking until almost the bell rings, there is no communication other than from the teacher to you and you reading a book alone. And you don't have any communication with your classmates, with the professor or the teacher. So it was very extremely boring and not really a lot of information… You just heard information and if you didn't catch it, you just didn't catch it. So it just flew by… It wasn't exactly very good environment.

In contrast, in the STEM S.O.S class environment, they started to communicate with their peers and teachers, and develop their communication skills. Student 5 summarized the communication process:

> We work in-group a lot of time and we have to talk otherwise, like he put people different group but like not everybody is on the same page so basically we have to talk a lot if you want to get the topic otherwise.

Students are also required to present their works in science festivals in their schools and international conferences like I-SWEEEP. This also helped students communicate with others such as teachers, professors, graduate students, and other participants. Student 7 uttered this as follows:

> It was actually kind of intimidating at first- talking to the professors- I didn't know what to expect but now I'm able to talk to them one on one like with well understanding as

> well as when visitors come here we have to present projects or something like that I'm able to present it well so that they understand it.

The student 9 stated that, "I did develop communication skills and how to present topics to people". Students are really glad to acquire communication skills and see these skills are really vital. Student 3 indicated that with the following statement "just communication skills in general huge thing". "I feel like teacher kind I like having back and forth communication like really helps you" is also the statement that clearly shows the importance of developing communication skills to assist students.

2.b.e. Collaboration skills

The last category of the impact of 21st century skills is collaboration. Students are required in the STEM S.O.S. model to study and collaborate with other students. They believed that the STEM S.O.S model helped them get along with other students, get help from experienced students, and work together to complete projects. The following expression, "We were kind of able to learn from each other" elucidates their collaboration noticeably. Student 6's statement revealed the level of collaboration among students as follows:

> I guess because you are not doing it by yourself only, you have other people doing it and it's a good club to meet other people other grades like friends like all the people in here, well most of them, are seniors and they all know me and we all speak even though I'm a 10th grader, you know? It's just really nice.

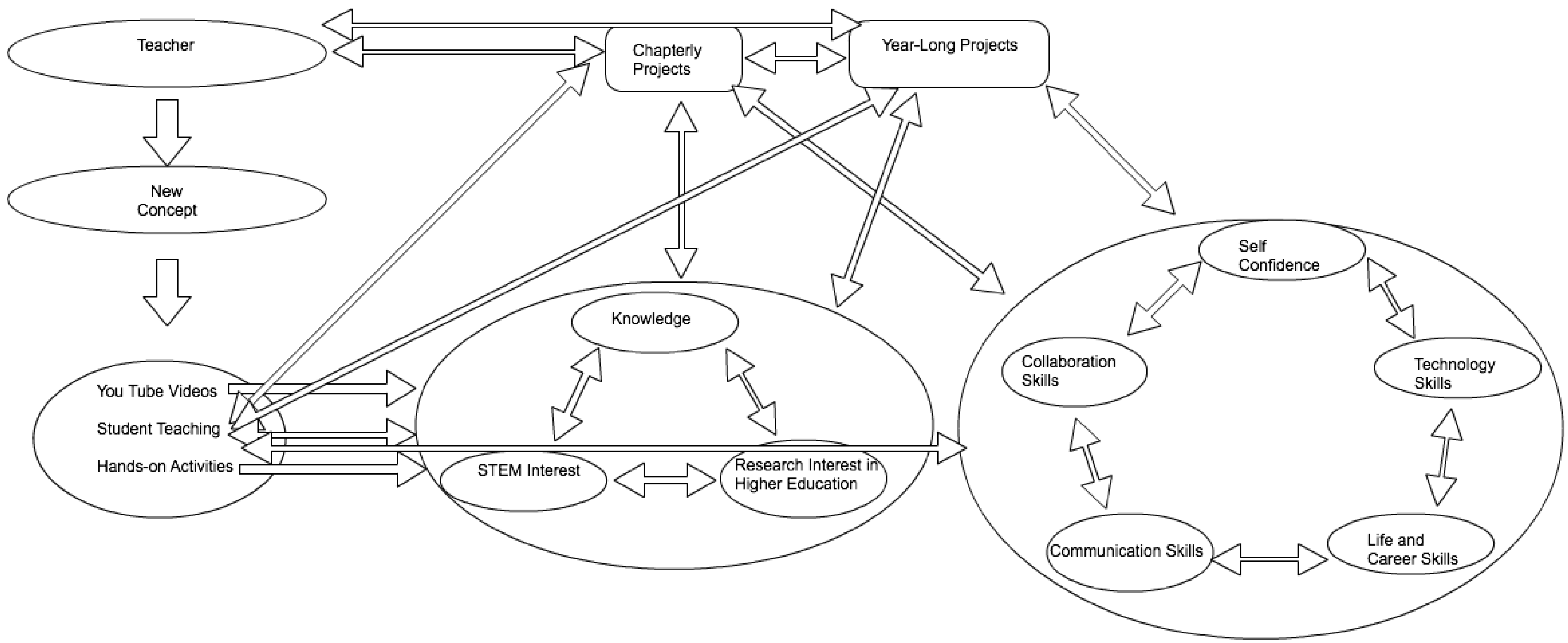
After a while, the collaboration among them proliferated desirably. They started to help each other willingly not only on scientific studies but also when they get sick or in need. The extent of collaboration was beyond school borders and this improved the school climate throughout the school semester. The student 5 expressed it sincerely:

> Like we're nice to each other and we help each other out and if a person needs help, like if their partner is sick like if they have a cold and they need somebody to fill in for them, then definitely you can find anybody who would be willing to just like help you out.

Overall, all these components of the STEM S.O.S model helped students benefit both academic and 21st century skills gains.

Figure 3

A grounded theory of STEM S.O.S. and Its Components and Benefits for Students



Discussion and Conclusion

Because the STEM S.O.S. is a novel model that was developed to improve K-12 STEM education, we wanted to see to what extent it is effective with students in terms of its components and benefits for students. After performing the coding process (open, focused, and axial coding), student interviews revealed that hand-on activities including YouTube videos and experiments, and student teaching from Chapter and Year-Long Projects are the main components of STEM S.O.S. teaching in the suggested grounded theory. The effective implementation of these components in the STEM S.O.S. model not only produced two fundamental benefits, Academic, and 21st Century Skills, but also helped circulate the sub-components of these two gains. That is, through the STEM S.O.S. model, students improved their knowledge/conceptual understanding, STEM interest, and research interest in higher education and developed self-confidence, technology, life and career, communication, and collaboration skills; and these skills continued to improve circularly.

Starting from the beginning to elucidate the whole process of grounded theory of the STEM S.O.S. and its components and benefits for students, teachers initially acted as role models by teaching new content in an original way. One of the discussions among teachers is whether they can prepare their students for standardized testing by using active teaching methods like Project-based learning when only standardized testing scores matters for schools (Needham, 2010). But it seems that teachers in the STEM S.O.S. overcame this problem because teachers first teach the content by actively lecturing it. On the other hand, the problem with lecturing is that students' attention begins to wander after 15 minutes of a lecture (Dowd & Hulse, 1996). However, the STEM S.O.S. model solves this problem by engaging students with YouTube videos, hands-on activities, and student teachings as one student put: "Except when he is doing the initial lecture, he doesn't do much talking which is good. Initial lecture, he introduces the ideas, he introduces the chapter or whatever the subject area is. Then we have videos, we have demos, we have student teaching, student all the time" (Student 4). Indeed, the literature says that students learn better when they are at the center of the instruction and they take the responsibility for their own learning (e.g, Blumenfeld, et al., 2011), two central components of Project-based learning (Pearson, Barlowe, & Price, 1999). Therefore, this results in students creating connections between the concept and its real life applications without being forced to memorize numbers or formulas: "… the way he teaches [is] good because instead of making you memorize things, he shows you how every things are connected, he shows us how every laws connected to one another (Student 10). This is parallel with the research on situated cognition indicating that learning is enhanced if the context for learning resembles the real-life context in which the materials learned would be used (Collins & Duguid, 1991).

Chapter and yearlong projects are central to the model. Because students mostly perceive project completion as a fun privilege, they develop ownership of the projects and really take responsibility for their learning. This might stem from students' admiration of their science teachers during classes where they complete hands-on and mind-on experiments, characteristics that make their *science teachers charismatic* as one student described. Also, they get extra credit for anything they do extra for their projects. Therefore, they try their best to do something different and new, thus learning happens concurrently. Also, completion of projects requires many personal and interpersonal skills and technology use. Because research found that high school graduates are not ready for college curriculum (e.g., Anderson, 2013) and college graduates are not ready for workforce in terms of necessary skills (e.g., Grassgreen, 2014), developing personal, interpersonal, and technology skills has become more important than ever.

For instance, students are required to do video a presentation of their assignment. To prepare a video presentation, students have to take pictures of each and every step of the experiment and materials, record the important episodes of experiment, and put them in order in the movie. They also have to insert any graphic that will show the change in measures at the time of, for instance, collision as well as the collision of the cars. They have to collaborate and get help from other students during completion of some projects without any formal requirement. In addition, they have to make a website of the experiment and upload the video presentation to the Harmony You Tube page. What's more, students have to present their products not only in the classroom but also to audiences during school STEM festivals, ISWEEEP competitions, and STEM expos. Then, it is not surprising to see that students develop skills including self-confidence, technology, life and career, communication, and collaboration that are necessary for the 21st century workforce (Pacific Policy Research Center, 2010). As they get positive feedback from participants and viewers, they become more motivated, self-confident, better presenters, and experts in the content they present. Accordingly, this changes their attitudes towards science positively; they may develop STEM interest as in the social learning theory of Albert Bandura, (1977). This is congruent with research findings in which studies reported that student attitudes toward STEM education proved to be a major factor in order to increase student interest in STEM subjects (e.g., Mahoney, 2010). Also, we learned that students mostly cultivate STEM interest during high school years (Archer, DeWitt, & Wong, 2013: Maltese & Tai, 2011) and see daily life connections with hands-on activities (Myers & Fouts, 1992). Therefore, the role of chapter and yearlong projects seem to be very central to the STEM S.O.S. model.

Teachers' role in the STEM S.O.S. model is also phenomenal. They not only teach the content and make teaching engaging, involving, and fun but are also available to their students during the chapter and yearlong project completions. They provide timely feedback and facilitate them when they need help. Teachers' friendly approach to their students make student-teacher interactions two-sided and results in students' learning, great student projects, and positive student attitudes towards science during chapter and yearlong project completion process. This explains why students, especially female students, who chose STEM majors reported that they were inspired and influenced by their science teachers (Microsoft Corporation, 2011).

These aforementioned elements (YouTube videos, Student teaching from Chapter and Yearlong Projects, Hands-on-Activities) suggest the fundamental components of a successful STEM S.O.S. model that can be emulated in other contexts.

Conclusion

Effective STEM instruction depends on teachers' professional and affective abilities to deal with student biases about science including why I do need to learn science, there are lots of formulas and terms, and science is for only geeks. This research described the STEM S.O.S. model and explored how it helped students grow both academic and 21st century workforce skills. The emerging theory suggests that there are two core elements of the model; teacher-led teaching and student-directed and completed chapter and yearlong projects. The study further identified the student benefits as a result of the model; academic and 21st century skills. If students are to gain academic knowledge, develop STEM interest, research interest in higher education, and 21st century skills, then this model should attract the attention of parents, educators, other students, and policy makers to improve the quality of STEM education and increase the number for STEM pipeline. So far, the STEM S.O.S. model seems to accomplish this goal because Harmony schools' STEM matriculation percentage is higher than the national average (66 vs 33) (Sahin, 2013).

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Appendix

Interview Questions

Hi, we are going to ask you some questions about your science experience at your school.

1. Which science course are you taking this year?
2. What other science course have you taken so far?
3. Do you like science classes?
4. How is science, like physics, taught here?
5. What do you say about your science teacher's teaching?
6. How does he/she start teaching a class with?

7. Is it different?
8. Why do you think it is different?
9. What is your role in your science classroom?
10. What is your teacher’s role?
11. How would you describe your science experience at Harmony?
12. What do you do different?
13. In which ways does Harmony PBL or science teaching help you?
14. What skills do you use in completing science assignments?
15. What skills do you think you develop in the end?
16. Where do you think you will use the skills you develop at your school?
17. Is there anything else you want to add about your science experience at Harmony?