STEM Students on the Stage (SOS): Promoting Student Voice and Choice in STEM Education Through an Interdisciplinary, Standards-focused, Project Based Learning Approach

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Abstract

In the global economy that is intertwined with scientific and technical knowledge and innovation, raising a Science, Technology, Engineering, and Mathematics (STEM)-literate generation of students has emerged as one of the paramount goals of most countries. Educational models that contribute to meeting those countries' goals have become important in education. The absence of standards-focused, ready-to-teach teacher and student materials and lack of regular teacher trainings are some of the barriers attributed to the current STEM teaching approaches. Against this background, we investigated a successful STEM teaching model that has ready-to-teach materials, standards-focused, regular teacher professional trainings and student choice and voice that utilize both classroom and out-of-classroom projects as a solution to the aforementioned issues. The purpose of this research is to examine a new STEM teaching approach developed by a public charter school system, Harmony Public Schools (HPS). We used theoretical sampling; 11 semi-structured interviews were conducted with high school students. Grounded theory and constant comparative analysis were utilized. Study findings have revealed that the students were active learners most of the time, presenting and sharing their findings with classmates and visitors. Thus the title of this research, *STEM Students on the Stage (SOS)*, is used to describe this model. In addition, emerging substantive theory suggested that STEM SOS model helped students learn STEM subjects better, cultivate STEM subject interests, and develop skills for their college and professional lives. Implications of the effect of this model on K-12 students' learning experiences are discussed in detail.

Scientists, technologists, engineers, and mathematicians are high-tech workers who have the knowledge to turn the wheel of the global economy (Craig, Thomas, Hou, & Mathur, 2011). Accordingly, the importance of science, technology, engineering, and mathematics (STEM) education cannot be underestimated for countries in an innovation-driven economic world (Top & Sahin, 2015; Sahin, Ayar, & Adiguzel, 2014; Sahin, 2013). Several reports have highlighted the links between a well-rounded K-12 STEM education – to prepare the next generation's scientists, leaders, and innovators – and countries' economic leadership (e.g., National Academy of Sciences, 2007; President's Council of Advisors on Science and Technology, 2010). Yet statistics show that there is a disproportionate growth in terms of numbers and quality of STEM workers (Mahoney, 2010; Lacey & Wright, 2009). Thus, developing a quality STEM education that prepares students for the 21st century workforce becomes paramount for each country'seconomic wellbeing.

For this purpose, different approaches have been pursued to teach STEM subjects in K-12 settings. Some of the research-based methods for 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) and 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). For the most part, 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 an effective STEM education program (Laboy-Rush, 2011). These methods are successfully implemented because of the models' integration of cooperative learning, working in teams to do research, testing theories and producing 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). However, there have been some gaps in the implementation of current conventional PBL models (Mapes, 2009; Marx et al., 1997), namely, a) teachers don't have access to ready-to-teach materials including teacher guides, student handouts and assessment materials; b) there is a lack of regular teacher trainings; and c) non-aligned PBL lessons that don't prepare students for standardized testing. In this study, we investigate a new STEM PBL teaching approach that incorporates a full curriculum, including ready-to-teach teacher materials, PBL projects for all core subjects, regular teacher trainings and aligned with multiple state standards.

STEM Case in the United States and STEM SOS Model

Statistics have shown that U.S education suffers from lack of rigorous K-12 education, especially in STEM areas. For instance, the National Assessment of Education Progress (NAEP, known as "the Nation's Report Card") revealed that only 26 percent of America's 12th-graders scored at or above proficient in math (Bertram, 2014). In another example, "only 40 percent of Americans about to enter the workforce, military, college, and voting age are able to perform basic mathematics" (Bertram, 2014, pg.1). We already know that American students lag behind their counterparts in international math and science tests (e.g., TIMSS, PISA). Accordingly, there is a shortage of STEM majoring professionals (NRC, 2011; Schmidt, 2011). To address these problems, integrated STEM education or Project-based Learning (PBL) has been proposed (Fortus et al., 2005). Limited research on PBL has yielded promising findings, such as an increase in student interest in and understanding of STEM and developing skills in collaboration and problem solving (Fortus et al., 2005). Likewise, Harmony Public Schools (HPS) has developed its own STEM approach that incorporates project-based and inquiry-based learning called "STEM Students on the Stage (SOS™)" through the Race to the Top grant funded by the U.S. Department of Education with the goal of not only increasing students' STEM knowledge and interest, but also producing self-motivated and self-regulated learners (Harmony STEM Program, 2013). STEM SOS 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). In contrast to other conventional PBL approaches, students have to complete multiple projects, including a level I project followed by either regular level II or advanced level III project.

Students are assigned two level I projects per semester on each core subject (Mathematics, Science, ELA, and Social Studies). These are completed within class with a group of 3-4 students aligned with the curriculum's scope and sequence within a week. The final product consists of an investigation report of their work with a digital presentation of the project. Student projects are assessed with related rubrics in each core subject for each project separately.

In addition, students must complete one interdisciplinary STEM SOS project from either mathematics or science, as well as an assignment for social studies and ELA as an interdisciplinary component of the projects they choose or to which they are assigned. Level II projects are year-long and completed outside of classroom. The use of technology is a must and is integrated in each and every step towards project completion. Another requirement of any level II project is the creation of a brochure summarizing a student's project, including QR codes of student websites and a digital presentation of the final product. All student products are saved online and are available to the outside audience with students' permission. Teachers have access to all STEM SOS materials, including teacher guides, student handouts, assessment materials, rubrics and projects. Teachers also receive regular trainings on updates and implementation of those projects. For each level, there are a number of tasks students have to complete in order finalize their end product – an e-portfolio.

Students who complete their STEM SOS projects present their products at their annual school STEM festival. Students who are willing to present their level II projects at STEM Expo exhibitions, International Sustainable World Energy, Engineering, and Environment Project (I-SWEEEP) Olympiad and other STEM-related events and competitions, either by special invitation or by registering. For example, a group of Harmony Schools students have presented their level II projects at the annual Plasma Science Expo in New Orleans, Louisiana. The event is organized and hosted by the American Physics Society in partnership with MIT, Princeton and West Virginia University. The Harmony Public Schools science department organizes an annual STEM SOS website competition to encourage students to complete their projects. Each year, approximately 50 students receive iPads as prizes in the competition. To show appreciation for the teachers' hard work, teachers receive either iPads or monetary awards for their classroom projects, based on the number of e-portfolios their students complete. Another competition in which students participate is an annual digital story-telling (DISTCO) competition. This is completely voluntary and only those who believe their digital presentation of the project is good participate. The awards students receive vary from a $8,000 scholarship to iPads.

Level III projects are for students who enjoy the challenge of creating and conducting their own research and product (Top & Sahin, 2015; Sahin & Top, 2015). The content is rigorous and deserving of extra credit upon completion. The project's scope, driving questions, expectations, materials and guidelines are decided in collaboration with teachers.

A sample STEM SOS level 1 project uses the change in momentum of an object during a collision related to the impulse associated with the collision as a driving question. A digital presentation of a sample student level 1 product can be found at http://tiny.cc/mfybzx. A sample level II project is about binary numbers and how to visualize and learn to count in binary. A student product (e-portfolio), including his website, brochure, digital video presentation and interdisciplinary connections, can be found at this URL link: http://tiny.cc/mkybzx.

The purpose of this study was to investigate and determine the components of a successful STEM teaching approach in a high school where students are engaged, take responsibility of their learning and develop STEM literacy and awareness as well as acquire important workforce skills. The overarching research question we sought to answer was:

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

Method

Settings

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

Participants

We chose a high school that have been implementing the model for three years. We invited 19 students, with 11 of them volunteering to be part of the research; the sample was 11 students: 5 seniors, 5 juniors and 1 sophomore. We conducted semi-structured interviews with them. The 11 students were taking one of the following courses: Pre-AP Physics, Chemistry, or AP Physics. A different teacher taught each of the courses.

Procedure

A broad research question was formulated as to how learning in the STEM Students on the Stage (SOS) learning model occurs and the benefits ultimately gained by the students. The questions were addressed by a grounded theory study as the method of analysis to explore the new teaching style in a public charter high school and to develop a functional theory in terms of how it is taught and what comprises teachers' and students' roles.

Grounded theory methods are 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 appreciate the value of grounded theory methods (Charmaz, 2010). We recognize our position within the studied world, locating ourselves within our research interest in codifying the STEM SOS model and revealing student gains through the model. Samples were collected from one of the Harmony Public Schools in which the STEM SOS model has been implemented as a pilot study since May of the 2011-2012 school year. The model was officially launched in all HPS campuses in the 2013-2014 school year. As of June 25, 2015, Harmony high school campuses have started implementing the STEM SOS model. The Harmony middle school use of the STEM SOS model is being developed and has been in trial in several campuses.

Theoretical sampling was utilized in the present study, which was grounded in emerging concepts and associated with understanding new people, to advance or refine theoretical saturation – not merely to fill gaps in the data (Charmaz, 2005). An obvious example might be the first application of grounded theory, "Awareness of Dying" (Glaser & Strauss, 1966), which centered on a grounded theory on the effects of awareness on the interaction with dying individuals. In the course of the study, the researchers visited a number of medical services. When doing so, they observed certain types of services at other types of hospitals so that their scheduling of types of services developed a conceptual structure. The observations continued at two, three, and four weeks to check items that might have missed in the initial observations. In this respect, they used theoretical sampling by observing various medical services for a grounded theory of awareness. Similarly, we have talked with several students who have been exposed to a novel model, STEM SOS. In the current study, the sample was identified and the data were collected by conversing with participants exposed to the model 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). The students who enrolled in the program and were interviewed were all volunteers and consented to their involvement with the study.

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). We wrote memos throughout the entire process, which helped in relating codes and categories to each other. Then, we applied focused coding by constantly comparing each initial code with similar ones in order to develop categories and sub-categories from the raw data. While the categories were being produced, we performed axial coding through relating categories, via the combination of inductive and deductive thinking. Below is 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 SOS model.

Findings

The findings revealed how learning in the STEM SOS model occurs and what student benefits are gained in the end. Analyses of student transcripts suggested two core categories (1) how STEM SOS teaching works (see Figure 1) and (2) impact on student gains (see Figure 2).

1. How STEM SOS Model Works from Students' Interviews

To the students, STEM SOS model has two critical aspects: (1.a) teacher-directed teaching and (1.b) student projects. Later, student responses showed that teacher instruction has three important components: (1.a.a) lecturing or teaching the theory, (1.a.b) hands-on activities, and (1.a.c) student teaching. Student projects include chapter (optional) and yearlong projects. In addition, student interviews suggested two fundamental student gains under (2.a) Academic and (2.b) 21st century skills. Furthermore, the first student gain includes 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.

SOS model

1.a. Teacher-directed Teaching

1a.a *Lecturing.* This is the element that occurs within the classroom. In the SOS model, teachers start a new lesson by lecturing about a concept to lay a foundation for upcoming sections, as student 1 stated ". . . Initial lecture, he introduces the ideas, he introduces the chapter or whatever the subject area is." This includes direct lecturing on the concept as well as asking questions of students and observing if there is any area in which 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 differs from average lecturing because the teacher is not only lecturing but is also actively watching students' gestures and answering their questions to ensure that everyone 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.
>
> Also, teachers don't simply lecture but also explain any formula or theory, step-by-step and/or with an example from daily life with hands-on experiments or videos.

Teachers have a separate curriculum to teach content apart from the STEM SOS projects.

> 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 law's connected to one another. (Student 10)
>
> Moreover, one of the important elements of this

section is giving students many opportunities to become involved. This part is enriched with several different activities including hands-on experiments, YouTube 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 is central to teachers' lecturing or teaching and makes the lecture segments very engaging, resulting in an increase in student involvement. To give an example out of many similar student statements, Student 9 very clearly described the benefits of STEM SOS in terms of students' involvement as:

> [SOS] 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.

1.a.c. Student teaching. The last segment of the teacher-directed lecturing is student teaching, in which the teachers assign projects to a student or group of students for each chapter before they start teaching about the content. The teacher asks the related group of students to teach and do the experiment that explains the content or concept, which helps students in multiple ways, from better learning to learning to do presentations before a class: 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 emphasized the role of student projects in terms of better learning:

> Let's say he makes us do an experiment like a roller-coaster back there and after we completed, after he teaches us how to construct it, how all the formulas

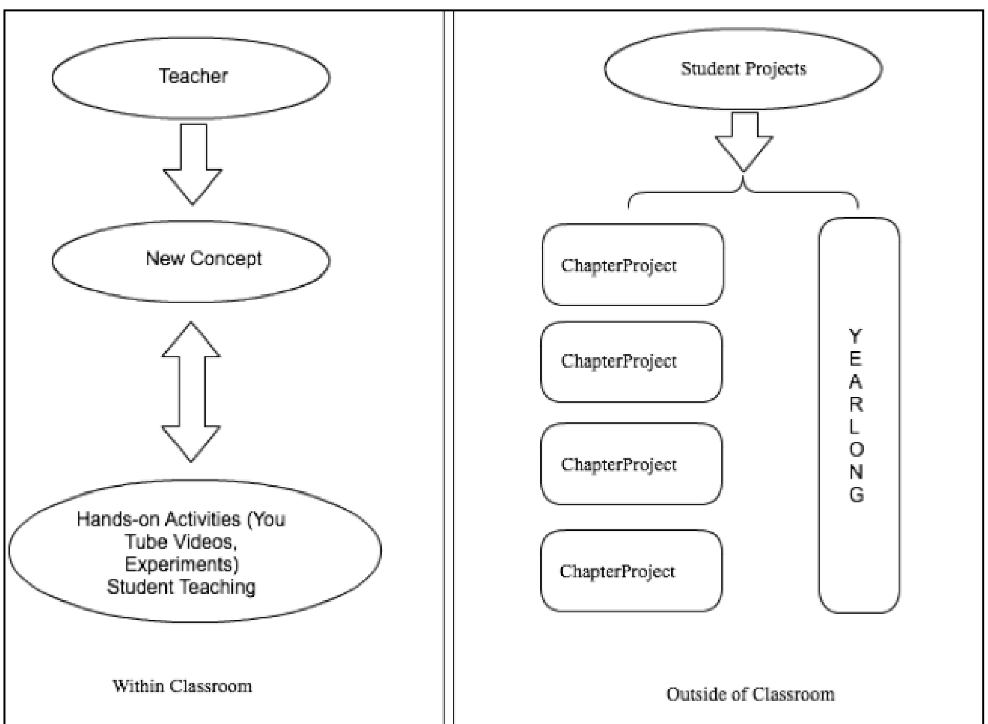

Figure 1. STEM SOS model from students' perspective demonstrating how SOS teaching works.

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.

The student acts as a teacher, which helps both that student and other students to learn the content and benefit by increasing self-confidence, knowledge, and in developing positive attitude towards science subjects.

1.b. Student Projects

Student projects are of two types with two goals: students are provided with a short-term project that is related to the content they learn within each chapter. A student or group of students is assigned to prepare an experiment or hands-on activities. Part of their responsibility is to present their experiment while related content is being taught. The second type of project is a yearlong and is completed out-of-classroom. Students choose those projects from a list of projects that is 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 pictures of each material used to complete the project, sets of short video episodes of experiments, related graphs, tables, and conclusions. Student 3 explains the process: "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." Teachers record each student's project completion in their Google spreadsheet, checking students' products and providing feedback. Then, students revise the areas about which they received feedback: "We basically… we have to go home and then fix them up. And put them together…" (Student 3). Students show 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 in their homes. Student 3 continued to explain how they work to complete the projects they chose: "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."

Students are required to complete all the requirements as part of their yearlong projects out-of-classroom. These include, but are not limited to, a project website, a brochure summarizing the project and including QR codes for the project website and video. They also upload their digital presentation videos to their YouTube channels. Yearlong projects are usually an individual project that pushes students to collaborate with other students to complete it. Students find many opportunities to present their science demos before an audience. For example, each Harmony school does a STEM festival each spring semester in which all students who completed STEM SOS projects participate and present their projects. They are also invited to present at different STEM EXPOs and science Olympiads. These presentations 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' academic and 21st century skills. Students were provided in-depth information about their gains during the interviews. The information provided via the interview questions about student gains revealed two categories, academic and 21st century skills (see Figure 2).

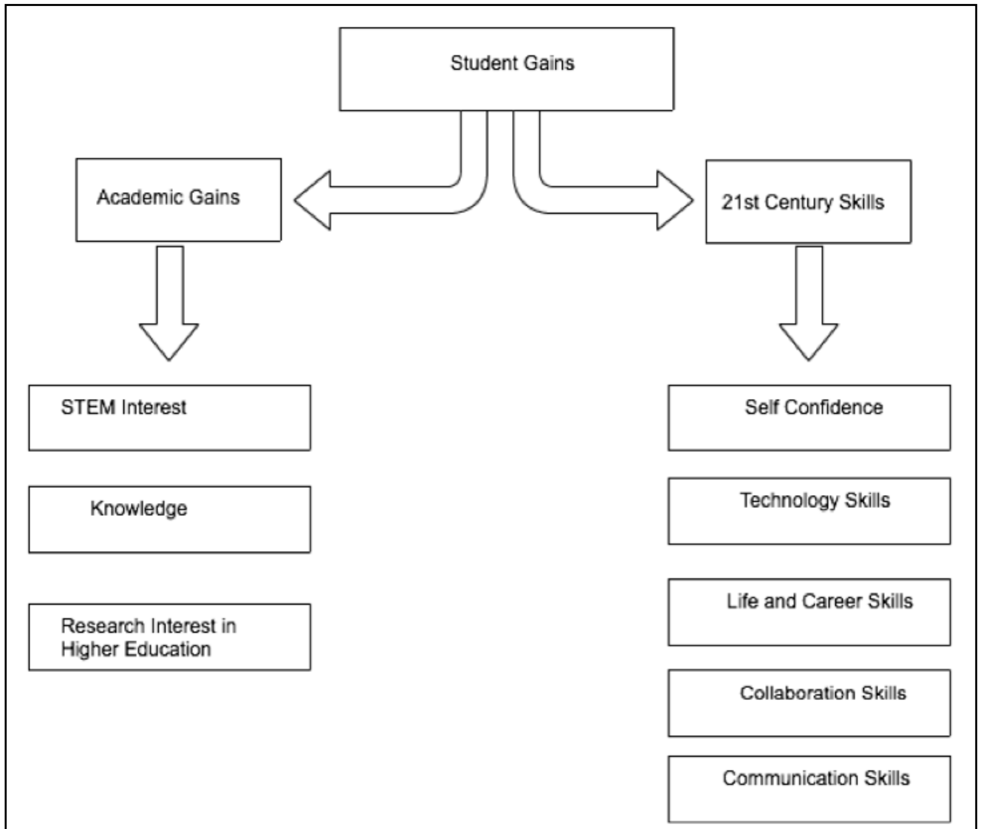

Figure 2. Student gains from student interviews.

2.a. Academic

Student interviews suggested how they perceive the model in terms of their academic growth. For example, Student 5's expression of "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 how they had learned to solve a problem. 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 [the] real world environment with me, it helped me developing something very useful." This category leads us to three sub-categories: STEM interest, knowledge and research interest in higher education.

2.a.a. STEM interest

Students reported that they developed STEM interest through the STEM SOS model. They started enjoying scientific experiments because it was fun for them. Student 2 stated this 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.

STEM subjects seemed to attract their attention; one student stated that "science demos are 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 accustomed to being good at science but became really interested in it. Student 3 said, "I have never really been good in science, but I have learned that when you really focus on it, you add interest." In addition, Student 2 clearly expressed this interest:

> I always like 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.

2.a.b. Conceptual Understanding

Students all agreed that they learned a great deal through this style of teaching. Students felt that they increased their understanding of science concepts taught through participating, building their demos, and conducting experiments. "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 Student 11, who demonstrates how lifelong learning happens through the STEM SOS Model. A second student underscored the importance of visuals of the STEM SOS to their understanding of concepts by stating, "So visual learning and letting you know what it is all about it helps to understand everything about it." In addition, the STEM SOS not only helps students learn the content but also allows them to understand 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."

Student 4's statement also illustrated their confidence due to increasing 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 active learners of the things happening around them. The SOS 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 related to the impact of academic gains is research interest in higher education. In this category, students discussed their intention to continue conducting research in higher education. Student 6 stated very clearly:

> 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 . . . 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.

2.b. 21st century skills

Apart from academic gains, the findings also showed the impact of the STEM SOS model on students' social and emotional gains. Students started to feel that they could achieve such things as presenting to groups, communicating with other students and people from outside, making a connection with the things happening around them, etc. We collected those skills into five groups: self-confidence, technology skills, life and career skills, communication skills and collaboration skills.

2.b.a. Self-confidence

Students championed the model because, through it, they developed the confidence to be able to talk to a crowd, and communicate interpersonally. After exposure to the model, completing the projects and presenting in different venues, they became more confident about their learning. 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..." The same student expressed those 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 improves that ability more."

Students overcame their fears of presenting or talking before groups. Student 1 stated:

> . . . 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 SOS helped them achieve that. Student 6's observation illustrated that belief:

> . . . 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, '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

Because STEM SOS integrates technology into each and every task of the projects, students found many opportunities to develop their technology skills. Student 2 described "Making your websites, linking a picture. So I didn't know how to do that."

"When I go home, I am usually working on editing the videos and putting them together" said Student 3, illustrating that students are dealing with the technological tools in multiple locations. Therefore, it was not a surprise for a student to say, "Now I can create my own website and make a movie of what I want, thanks to the STEM SOS."

2.b.c. Life and career skills

It seemed that students started recognizing the connections between things around them and what they learn in their STEM classes. The relationships between theory and real life have made sense to them. For instance, Student 5 states, "this [the things we learn in class] helps you learn from and it helps in your real life, for example, in a kitchen or while driving." In addition, students started developing skills that helped them in their personal lives:

> 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. (Student 7)

Because STEM SOS promoted and required collaborating and working with others, students seemed to have acquired empathy skills in helping others such as the poor, unhealthy, or needy. Therefore, they wanted to share what they learned through STEM SOS with others as a voluntary service:

> . . . as part of my community service hours, I go to families and homeless people so I can notice different things like whether a child has been abused or the homeless man is also doing, you know, illegal... 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 [at least] matches their needs.

The other positive thing that STEM SOS helped them to develop is passing the skills and knowledge they

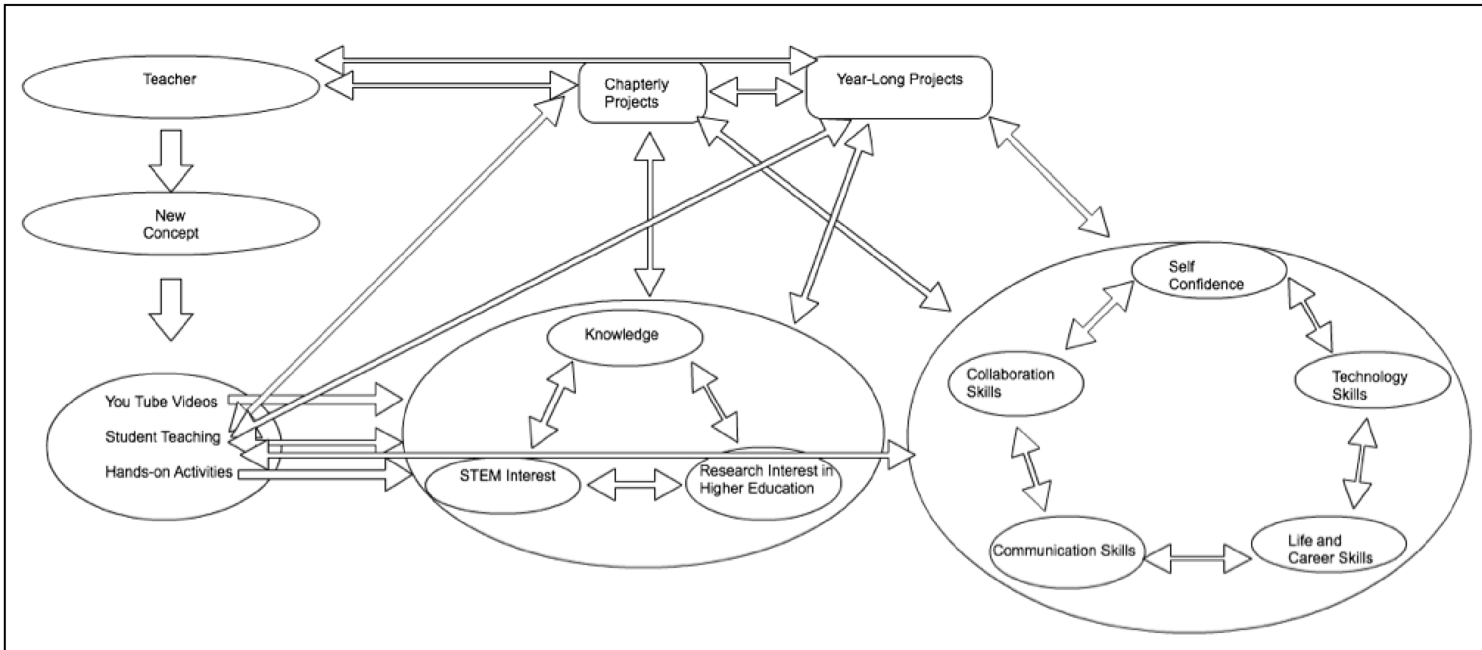

Figure 3. A grounded theory of STEM SOS and its components and benefits for students

learned via the model to their children: "It is always nice to know so I can always teach to my children." Overall, the skills students developed via STEM SOS can facilitate both their personal and career lives.

2.b.d. Communication skills

So far, we learned that students developed important skills that will help them both in their academic and personal lives such as content knowledge, self-confidence, and social skills. In addition, the STEM SOS enabled them to communicate with friends, visitors, mentors, professors and people from all walks of lives throughout their project completions, school festivals, and STEM EXPOs:

> We work in-group a lot of time and we have to talk . . . like, he put people in different groups but like not everybody is on the same page so basically we have to talk a lot if you want to get the project get done. (Student 5)
>
> 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. (Student 7)

All these activities and interactions helped students of STEM S.O.S. develop advanced communication, public speaking and presentation skills: "I did develop communication skills and how to present topics to people." Some students were aware of the importance of communication skills in their current and future lives; as Student 3 noted, "just communication skills in general is a huge thing. I feel like a teacher [and] I like having back and forth communication, like, [it] really helps you." Over time, students may realize the importance of having such skills when they go to a college or for a job interview.

2.b.e. Collaboration skills

Because they have to complete several projects, each of which requires several collaborative steps (e.g., shooting a video of their experiment), students believed that the STEM SOS model helped them learn to get along with other students, to collaborate with students who are senior in experience and to complete a task together:

> 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.

The STEM SOS model requires students to complete projects that span the year; they spend an extensive amount of time with each other because projects are followed by other projects. This may have transformed their team relationships into real friendships. Therefore, they knew each other better and thus, they started helping one another beyond school borders, resulting in improved school climate:

> 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. (Student 3)

Overall, all these components of the STEM SOS model helped students gain both academic and 21st century skills.

Discussion

Because the demand for skilled workers in STEM is closely linked to countries' global competitiveness, active teaching approaches that place students at the center of engaging instruction that relates content to real life have become more important than ever. The researchers aimed to study a new and innovative STEM teaching approach, the STEM SOS, and to codify its components in terms of how it is taught and the ways in which it benefits the students. After performing open, focused, and axial coding, student interviews suggested that utilizing hands-on activities, including YouTube videos, experiments and student teaching of both chapter and year-long projects were central to the STEM SOS approach. Incorporating classroom (Level I and chapter projects) and out of classroom (Level II and III) projects created multiple learning opportunities as well as the development of important success skills for students. Overall, there were two groups of skills involved: academic and 21st century skills. These also helped with the sub-components of these two gains, that is, through the STEM SOS model, students improved their knowledge/conceptual understanding, STEM interest and research interest in higher education and developed self-confidence, technology skills, life and career, communication, and collaboration skills. Further, these skills continued to improve in a circular fashion.

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 matter for schools (Needham, 2010). But it seems that teachers in the STEM SOS did not have this problem because they have a separate curriculum wherein they teach content via the lecturing component. Although for students lecturing may become a boring style of teaching because they start to wander after 15 minutes of instruction (Dowd & Hulse, 1996), teachers in the STEM SOS solved this problem by engaging students with YouTube videos, hands-on activities and student teachings. This parallels research which has found that students learn better when they are at the center of the instruction and when they must take the responsibility for their own learning (e.g., Blumenfeld et al., 2011). Indeed, this is very true for this model, because students are always active and on the stage, either presenting a chapter demo and/or doing Level I investigation and presenting it to the class, and/or presenting their Level II or III projects, either before the class or to an audience at their school STEM festival or other occasions like ISWEEEP, etc.

Chapter and year-long projects are pivotal to the model. Because students frequently perceive project completion as a fun privilege, they develop ownership of the projects and truly take responsibility for their learning. This might stem from students' admiration of their science teachers during classes in which they complete entertaining and engaging hands-on activities. These make "science teachers charismatic," as one student described. Also, students earn additional credit for anything they do extra for their projects; therefore, they try their best to do something different and new and learning happens concurrently. Also, completion of projects requires many personal and interpersonal skills and the use of technology, in contrast to research that says college graduates are not ready for workforce in terms of personal, interpersonal, and technology skills (Grassgreen, 2014). In STEM SOS, students are required to prepare a video presentation of their assignment. In doing so, students must take pictures of each and every step of the experiment and materials, record the important episodes of that experiment and put them in order in the movie. They also have to insert any graphic that will help in explaining the experiment. They must collaborate and obtain help from other students during completion of some projects without any formal requirement. In addition, they have to build a website of the experiment and upload the video presentation to the Harmony YouTube page. Further, students must present their products, not only in the classroom but also to audiences during school STEM festivals, ISWEEEP competitions and STEM expos. Therefore, it is not surprising that students develop skills that include self-confidence, technology, life and career, communication and collaboration as well as cultivating positive interests towards STEM subjects. Indeed, recent data about Harmony students taking Advanced Placement (AP) courses show that students at all Harmony High Schools enrolled in AP Physics 1 most frequently among all other STEM and non-STEM AP courses (588 vs 499 (Non-STEM)). As they receive positive feedback from both participants and viewers, they become more motivated, self-confident, better presenters, and experts in the content they present. Accordingly, this creates a positive change in their attitude towards science; they may develop STEM interest as is described 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 increasing student interest in STEM subjects (Mahoney, 2010). Also, the researchers 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.

The role of teachers in the STEM SOS model is also phenomenal. They not only teach the content and make instruction 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 approaches to their students make
student-teacher interactions two-sided and result 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).

Conclusion

Effective STEM instruction depends on teachers' professional and affective abilities to deal with student biases about science. This research described the STEM SOS model and explored how it helped students increase 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 student benefits resulting from this 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 be brought to the attention of parents, educators, other students, and policy makers to improve the quality of STEM education and increase the number for the STEM pipeline. Thus far, the STEM SOS model seems to accomplish this goal because in longitudinal studies, Harmony schools performed better than their matched counterpart public schools in 9th, 10th, and 11th grade science state test scores (Sahin & Almus, 2015; Sahin, Willson, Top, & Capraro, 2014).

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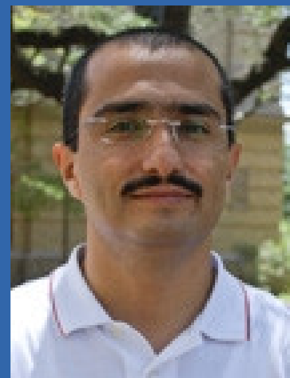

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Appendix

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?