

AC 2010-466: STUDIO STEM: NETWORKED ENGINEERING PROJECTS IN ENERGY FOR MIDDLE SCHOOL GIRLS AND BOYS

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Studio STEM: Networked Engineering Projects in Energy for Middle School Girls and Boys

Abstract

The US workforce of the 21st century reflects an increasing need to train and hire engineers, scientists, and technologists.^{1,2} Whereas, the current trend is to seek expertise from foreign nationals, the new agenda is to place a concerted effort on the training and development of US citizens in Science, Technology, Engineering, and Mathematics (STEM). Consequently, the researchers addressed this effort by exposing young people to STEM careers while focusing on design issues and concepts related to energy conservation and the environment.

In this paper, we describe the results of the initial implementation of Studio STEM in an informal setting for underserved youth: an after-school Boys and Girls Club in a rural Appalachian community. The curricular package used for this pilot study, called Save the Penguins, has been used in the past in formal, in-school settings with advantaged youth.^{3,4} In this iteration the researchers selected a different population and added an information communication technology (ICT) component to encourage technical literacy and collaboration. Additionally, volunteer mentor/facilitators were trained to coach and scaffold student understanding, providing a supportive, motivating presence in the studio. The theoretical framework of social constructivism was the driving force for curriculum design, and was present in data collection and data analysis. Students were observed and videotaped for the duration of the intervention (which took place in the fall of 2009), and were administered post assessments on attitudes in the form of surveys and interviews.

Introduction

The purpose of this study was to better understand how middle school students' attitudes and perceptions about engineering, science, and computer technology changed as they learned engineering design concepts in an after-school studio setting with mentor/facilitators and a collaborative ICT-embedded environment. The driving research questions guiding the investigation were:

1. How are students' perceptions of their abilities shaped by learning engineering design with an information communication technology (ICT) component in an afterschool setting?
2. How are students' attitudes toward engineering, science, and computer technologies impacted by the intervention?
3. How are the actions of the teachers and other facilitators related to the motivation students have to learn engineering and participate in the design activities?

These research questions were well suited to the theoretical framework of social constructivism because they addressed sense-making through social group activities and teacher scaffolding.^{5,6,7,8} They also addressed the expectancy-value model of motivation^{9,10,11} in that the

mentor/facilitators used with each group were trained to help motivate students and provide them with a sense of safety in risk-taking, and a sense of belonging to the studio community.

Overview of the curriculum

Penguins are in peril. As the Earth warms, the oceans warm and ice melts, and penguins lose habitat. They also lose food sources like krill, which not only feed on the algae growing on the pack ice, but rely on the protection of the pack ice.¹² The Emperor Penguins in Antarctica are in severe decline due to climate change.¹³ South African penguins are actually leaving their nests to cool off in the water, placing their eggs at risk to attacks by gulls.¹⁴

One major goal in the Save the Penguins studio curriculum is to help students recognize how their behaviors at home can affect how penguins are faring in the southern hemisphere. The energy we use to heat and cool our houses comes from power plants, most of which use fossil fuels. The burning of fossil fuels has been linked to increased levels of carbon dioxide in the atmosphere, which in turn has been linked to increases in global temperature. This change in temperature has widespread effects upon life on Earth, such as the life of penguins. If buildings were better insulated, they would require less energy for heating and cooling. If engineers designed innovative insulating building materials and if builders used them in our homes, schools, and workplaces, it would have a positive impact on the environment. This is the problem presented to students - how to create better dwellings for us all- people and penguins.

The teachers in this study first introduced the science concepts of conduction, convection, and radiation, and performed demonstrations illustrating all three methods of heat transfer. These discrepant event demonstrations were designed to provoke cognitive dissonance, challenging students' misconceptions and naïve conceptions of heat transfer. Students were introduced to the computer technology they would be using for creating design drawings and sharing ideas and photos, and then they were given the design challenge: to build a small structure which would keep a penguin-shaped ice cube from melting in a hot test oven. This structure and the ice cube within are an analogy to what is happening in the real world as global warming encroaches on penguins' habitat. Students designed and created this analogous structure to save their ice cube penguin while thinking about how engineers are doing the same thing on the global scale. Working as engineers with a design task, student were given a small budget from which to purchase a choice of available materials, and guided through experiments to test these different materials for their ability to reduce heat transfer. Material choices were: bubble wrap, aluminum foil, colored construction paper, colored foam sheets, metallic Mylar film, wooden sticks, cotton balls, and small paper cups. For a more detailed description of the curriculum, see Schnittka (2009 a)³ or Schnittka (2009 b)⁴.

In the after-school studio setting, students worked in small teams of two with a volunteer facilitator to test materials, design the dwelling, test the dwelling, and create virtual representations of their designs and ideas, write about their design decisions, materials used and final design. Volunteer facilitators were university students, and were key to motivating the students and keeping them focused on the design goals.

This curriculum was originally developed by engineering students and faculty at the University of Virginia as part of the Virginia Middle School Engineering Education Initiative, but was

subsequently revised and re-written by the first author after two years of testing in middle school classrooms and workshops with nearly 100 teachers. It was additionally modified for this particular intervention to include a technology component which allowed students to share their ideas and designs through computers networked together on the Moodle platform. Moodle¹ is a free software application that can be used create networked online or offline learning sites for collaboration within schools or groups, or between groups in different locations.

Design Studio Model

In Studio STEM, multimedia representations of the participants' designed artifacts were shared through the Moodle network. The Moodle system invites and supports the exchange of information so that students develop, collaborate, and comment on each other's work. This created an online collaborative environment that complemented the on-site activities of the young participants. When more Boys and Girls Clubs join our research effort, collaboration between students at geographically separate sites will be possible.

Recently, science, engineering, and information technology have employed the design studio as a pedagogical strategy to promote "reflection in action",^{15,16} peer critiques of works-in-progress,¹⁷ and an understanding of real-world problems.^{18,19} Recent ethnographic research on studio practices²⁰ describes how the cognitive context of the design studio affords a location for a deeper understanding of disciplinary principles and an ability to generate coherent and compelling solutions. Similarly, the integration of cognitive and social elements, the basis for the design studio, is critical to successful problem solving within groups²¹.

In Studio STEM, ideas and digital representations related to participants' designed artifacts were shared through online social networks. This system invited and supported the exchange of information so that students could develop, collaborate, and comment on each other's work – a critical part of the design critique in the studio. Participants learned how to be receptive to advice and opinions from viewers, which they in turn incorporated into new iterations of their design. This created an online collaborative environment to complement the on-site activities of the young participants.

Studio STEM used the design studio as a pedagogic model for introducing STEM through energy conservation as a focus area. Predicated on a common construct in architectural fields, the "studio" as physical and virtual space allowed students the opportunity to share design plans as "pin-up sessions" or "gallery walks." Students focused on, explained, and justified their designs in design critiques (or "crits"), incorporated the input from their peers, and refined their design ideas.^{22,23} Likewise, our approach in Studio STEM applies the "dual-space model"²¹ of the design studio which allows youth to clarify the content of the problem and its relational context, both essential to a design-based approach.

Motivation and Belongingness

Although teachers often claim that students are interested in and enjoy the use of innovative technology and engineering-design projects, there is little empirical evidence to demonstrate how such projects affect student motivation in science and math. The data gathered from this project

relate to constructs in the expectancy-value, self-efficacy, and interest theories.

Expectancy-Value Model of Motivation

Eccles and her colleagues have tested the expectancy-value model of motivation^{9,10,11} and found that students' expectancy for success relates strongly to their performance on a task, whereas their values relate strongly to their intentions and choice of activities.^{24,25,10,26} Thus, the power of the model is derived from the fact that students' achievement and motivation (e.g., their choice to engage and persist in something) can be assessed by examining their beliefs about their ability perceptions and values. For instance, Meece et al. (1990)²⁶ found that junior high school students' performance expectancies predicted subsequent grades, whereas their perceived importance of math predicted their future course enrollment intentions. In fact, students' beliefs about their abilities and expectancies have been shown to be stronger predictors of their future grades than their prior achievement.²⁷

Eccles and Wigfield (1995)¹¹ have also used factor analysis techniques to demonstrate empirically that achievement task value can be separated into at least three factors: intrinsic interest value, attainment value, and extrinsic utility value. Intrinsic interest value is defined as either the enjoyment experienced from performing an activity or the subjective interest an individual has in a subject. Attainment value is defined as the importance of doing well on a task. The extrinsic utility value of a task is the usefulness of the task in terms of an individual's future goals.

Belongingness

Many researchers believe that all humans have a need to establish and sustain caring interpersonal relationships.^{28,29} Baumeister and Leary (1995)²⁸ proposed that the need to belong has two main features. First, individuals need frequent personal interactions with another person. Second, individuals need to perceive that another person cares about their welfare and likes them, and that the relationship is stable and will continue into the foreseeable future. Caring relationships with instructors have been shown to be related to intrinsic motivation, positive coping, relative autonomy, engagement in school, expectancies, values, effort, cognitive engagement, self-efficacy, persistence, and performance.^{30, 31,32,33,34,35,36,37} Based on this research related to belongingness, we wanted to design a project in which the students could experience belongingness from both the instructors and the other students. Theoretically, such feelings of belongingness would lead these students to be more likely to achieve higher in engineering and science, be less likely to drop out of school, be more likely to enroll in engineering-related and science courses, and be more likely to select an engineering-related or science major in college.

Because of the importance of both expectancies and values on students' performance and future choice of activities, we wanted to develop a project designed to increase students' levels of expectancies and values related to engineering, science, and computers and the Internet.

Method

Participants

Students in an after-school Boys and Girls Club at a middle school in a mid-Atlantic state were asked to participate in the project. The club coordinator explained the project to the students and provided them with information and parental consent forms to take home to their parents. Students whose parents completed the consent forms were given permission to participate in the project.

Of the eight students who participated in the project, five students were boys and three were girls. All of the students were White/Caucasian. Their ages ranged from 11 to 14, with four 11 year olds (all sixth graders), one 12 year old (a sixth grader), two 13 year olds (a seventh grader and an eighth grader), and one 14 year old (an eighth grader) (Figure 1).

The studio instructors were two females in their late 20s. One was a Ph.D. student in education with a background in science teaching and over 5 years experience working in informal science institutions and after school programs. The other was a master's student completing her teacher certification. Both instructors received training so that they could implement the curriculum with the assistance of six volunteer facilitator/mentors who worked directly with small groups of students throughout the intervention. All of the volunteers were undergraduate students- three in engineering, one in biology, and two in the humanities.

Students met for one hour, once a week, for seven weeks during their regularly scheduled after school meeting time for the Boys and Girls Club. Students met in the middle school library, a location which was not being used during this time after school. The library was arranged with tables that seated four students and desktop computers arranged on tables along the walls.



Figure 1. Students, instructors, and mentors working together.

Data Collection

Data were collected through observations, questionnaires, and interviews. The studio sessions were videotaped with two cameras. One camera was stationary and captured the action of the entire studio. A second hand held camera focused on selective close-up action at tables as students were designing, or at computers as students worked together on their Moodle site or PowerPoint presentation. Students and mentors also recorded one another through the use of two Flip cameras that circulated around the studio.

On the first day of the project, the researchers gave students a brief questionnaire that contained questions about their demographic information. On the last day of the project, the researchers interviewed students by reading them items from a questionnaire and recording their responses directly on the questionnaire. A typical interview lasted about 15 minutes. The questions on the questionnaire included the items described in this section and two open-ended items that read (a) “What are some of the things that you liked most about Studio STEM?” and (b) “What are some of the things that you liked least about Studio STEM?”

Expectancy and Value Items.

The researchers designed the expectancy and value items on the questionnaire to measure the four constructs discussed previously in the expectancy-value model of motivation section¹⁰, including ability perceptions, intrinsic interest value, extrinsic utility value, and attainment value. Although this model makes a theoretical distinction between expectancy beliefs and ability perceptions, Eccles et al. have been unable to distinguish between these two constructs in their factor analytic studies.¹¹ As a result, we chose to use “ability perceptions” as a measure of expectancy in the present study because it was only possible to ask students about their abilities (as opposed to their expectancies) at the end of a project.

To measure each of the four constructs, the researchers created three, 5-point Likert-type items for which one of the three items assessed students’ perceptions of engineering, one assessed their perceptions of science, and the other measured their perceptions of their computer/Internet skills. We designed the items to be similar in format and content to those designed by Eccles and Wigfield (1995)¹¹ because their items have been shown to have excellent face, convergent, and discriminant validity, as well as strong psychometric properties.^{10,38} Similar items were used successfully in a study of a technology project implemented by Levi Alstaedter and Jones (2009)³⁹. A complete list of the items used in the present study is provided in Table 1.

Table 1

Descriptive statistics for students' ability perceptions and values as a result of Studio STEM

Because of Studio STEM:	M	SD
Ability perceptions		
1. my <u>engineering</u> knowledge and skills are (a lot worse/better)	4.50	0.76
2. my <u>science</u> knowledge and skills are (a lot worse/better)	4.50	0.93
3. my <u>computer and Internet</u> skills are (a lot worse/better)	3.88	0.84
Intrinsic interest value		
4. I now find <u>engineering</u> (a lot less/more interesting)	4.38	0.74
5. I now find <u>science</u> (a lot less/more interesting)	3.63	1.41
6. I now find using a <u>computer and Internet</u> (a lot less/more interesting)	3.75	0.89
Extrinsic utility value		
10. I now believe that knowing about <u>engineering</u> is (much less/more useful than I thought before)	4.50	0.54
11. I now believe that knowing about <u>science</u> is (much less/more useful than I thought before)	4.00	1.07
12. I now believe that knowing about the <u>computer and Internet</u> is (much less/more useful than I thought before)	4.13	0.84
Attainment value		
7. I now believe that learning <u>engineering</u> is (much less/more important than I thought before)	4.50	0.76
8. I now believe that learning <u>science</u> is (much less/more important than I thought before)	4.13	0.99
9. I now believe that learning about the <u>computer and Internet</u> is (much less/more important than I thought before)	3.88	0.84

Note: All items were rated on a 5-point Likert-type scale with the endpoints as noted in parentheses in the left-hand column of the table and the mid-point value (i.e., 3) labeled in a way that indicated "the same as before the project."

Interest/Enjoyment and Effort/Importance Scales.

The Intrinsic Motivation Inventory (available at <http://www.psych.rochester.edu/SDT/index.php>) consists of six scales that assess students' subjective experiences in performing an activity. The scales have been used in several studies and have been shown to produce scores of adequate reliability and validity.^{40,41,42} Researchers used two of the six scales and replaced the original scale words, "this activity," with the term "Studio STEM" for all of the items. The Interest/Enjoyment scale was used to assess students' interest and enjoyment in participating in Studio STEM (e.g., "I enjoyed participating in Studio STEM very much."). The Effort/Importance scale was used to measure the amount of effort that students put into Studio STEM (e.g., "I put a lot of effort into Studio STEM."). All items were scaled using a 5-point Likert-type format with descriptors at 1 (not at all true), 3 (somewhat true), and 5 (very true).

Teacher and Student Academic Support Scales.

The Classroom Life Instrument⁴³ contains scales for 12 factors that assess students' beliefs about the social climate of a classroom. We used two of the scales, Teacher Academic Support and Student Academic Support, to assess the extent to which students believed that their project instructor and peers provided them with academic support. We slightly altered the original items in both scales to include the word "Studio STEM" because we wanted to focus students on how they felt about this project and not other teachers or students. An example item from the Teacher Academic Support scale is: "The Studio STEM teacher cares about how much I learn." An example from the Student Academic Support scale is: "Other students in Studio STEM want me to do my best on this project." All items were scaled using a 5-point Likert-type format with descriptors at 1 (never), 3 (sometimes), and 5 (always).

Results and Discussion

In addition to analyzing results from the questionnaires and interviews, all videotapes were examined by focusing on three different levels of analysis, and by moving back and forth between these levels we tracked meaning making as it occurred in the studio among students, their mentors, and the instructors. The videotapes were viewed in full at least two times, with sections of the video watched multiple times in a more detailed analysis of dialogues and action.

Change in Ability Perceptions and Values Due to Studio STEM

Students reported that they increased their knowledge and skills in engineering, science, and the computer/Internet due to their participation in Studio STEM (see Table 1). These increased ability perceptions are important because, according to expectancy-value theory,^{10,26} students with higher ability perceptions should perform better on tasks in these domains in the future. It is important to note that we did not measure the actual knowledge and skills of the students; however, we believe that students' ability perceptions should be good predictors of their future achievement based on prior research related to ability perceptions.²⁷

As a result of participating in Studio STEM, students reported that they found engineering, science, and computers/Internet to be more interesting, more important, and more useful than before the project. These findings are important because these values have been shown to be strongly related to students' future intentions and choices.^{10,26,27} For example, students with higher values related to engineering should be more likely to enroll in more classes related to engineering and should be more likely to seek out opportunities related to engineering.

Tests of statistical significance were not performed to assess whether there were differences between the mean values on the items reported in Table 1 because the small number of participants in the study would not provide the power necessary to achieve meaningful results. However, the results were examined for patterns. Students reported that they gained a similar amount of engineering and science knowledge and skills, an amount that is larger than what they reported for the computer/Internet. This result is encouraging because it indicates that Studio STEM was successful in teaching students about engineering and science concepts.

The pattern of results for students' values indicates that Studio STEM had a greater impact on their engineering values than their science and computer/Internet values. This might be due to the fact that students had little to no knowledge of what engineering was at the beginning of Studio STEM; therefore, they had the most to learn about it. Nonetheless, we were encouraged that their new found values were in the positive direction.

Beliefs about Studio STEM

Students were interested in and enjoyed participating in Studio STEM, put a lot of effort into it, and felt supported by their Studio STEM instructors (see Table 2). Students also felt supported by their peers during the project, but to a lesser extent than they felt supported by their instructors. Given the importance of caring interpersonal relationships^{28,29} and our attempt to design Studio STEM with that component in mind, the results support the fact that students felt cared for by their instructors. One goal for the future of the project is to try to improve students' relationships with one another.

Table 2
Descriptive statistics for students beliefs about Studio STEM

Beliefs about Studio STEM	M	SD
1. Interest and enjoyment in participating in Studio STEM ^a	4.70	0.37
2. Effort put into Studio STEM ^a	4.60	0.48
3. Peer academic support during Studio STEM ^b	3.56	1.08
4. Instructor academic support during Studio STEM ^b	4.66	0.52

^a rated on a 5-point Likert-type scale labeled at 1 (not at all true), 3 (somewhat true), and 5 (very true)

^b rated on a 5-point Likert-type scale labeled at 1 (never), 3 (sometimes), and 5 (always)

The results of the two open-ended items that asked students about what they liked most and least about Studio STEM also suggested that they enjoyed the project and put forth effort in it. In terms of frequency, five students indicated that they liked working on building the penguin house, four students said that they liked making their own website, three students reported that they enjoyed creating the PowerPoint presentation, and two students said that they liked helping save the penguins. Two students said that they did not like writing on the story boards, but these were the only two things that students said they did not like about Studio STEM. As a measure of their motivation towards participating in the project, two students said that they wanted more time to participate each week.

Video Analysis

The first level of the video analysis is large-grained and holistic; we call this the Video Narrative. While watching the video, the analyst composed a written narrative marked frequently with time stamps. This written narrative provided a detailed description of the action in the video by topics, speakers, objects, and technology. These descriptions focused on dialogue and action: What are the speakers saying to one another? What are the participants doing? How are they using space, tools, and various technologies?

The second level is intermediate and is called the Significant Event (SE). The Significant Event identified segments of the Video Narrative and analyzes it in greater detail, emphasizing dialogue, content, and the kinds of tools the participants are using to make meaning as they come to understand the design problem and the design process. A SE is an occasion when the students and their peers, or students and instructors are making meaning about the design problem or process. SE is typically when participants are engaged in dialogue with one another or working with one another to understand the design and its relevance to energy conservation. In this portion of the analysis greater detail in dialogue was added to the Video Narrative.

The third level of analysis is microgenetic, and comprised a detailed analysis of dialogue in the Significant Event. This third level involves selecting several representative SEs and analyzing these segments of video in greater detail, focusing on the ways in which students and the instructor use questions, analogies, and metaphors as a means for understanding key concepts of energy in the studio.

Key Themes from Video Analysis

The key themes derived from qualitative analysis of video footage were motivation, mentoring, and pacing. Each of these themes connects with the survey results noted above in terms of students' emerging sense of their abilities and the ways that they valued their experience in Studio STEM.

Motivation.

Mentors encouraged students to continue working on their project when their motivation was flagging. Held at the end of the day, students often came to the studio tired after a day of schoolwork. When students appeared to lack inspiration, the mentor would initiate the action in the team that was quickly taken up by the students. Other times, when students became punchy and silly, the mentors were able to gently pull the students back to the task and infuse their conversation with lighthearted jokes, but keep them working on their projects. For the most part, students enjoyed the attention that their mentors offered and students looked forward to seeing their mentors and the instructor each week.

The competition of having the most energy efficient penguin house was also a motivating factor in the design process. Students expressed excitement as the results of the first test were measured and recorded. Comparing all the designs from the first competition inspired them to redesign so "they could win." Also, students quickly understood the concept of cost effectiveness and several teams were conservative in how they spent their energy dollars to purchase supplies. They seemed to appreciate the complexity of the problem, to both design an energy and cost-effective dwelling.

Mentoring.

Mentors were introduced into the studio after the second session, and were central to the students' progress and enjoyment of the studio design process. However, mentoring among the

teams varied in terms of assisting students to understand key concepts of energy. While some of the mentors were helpful in motivating students and in keeping them on task, the mentor's ability to facilitate thoughtful conversation varied. Questions prefaced with "how" or "what" did not elicit reflective responses from the students. Instead students responded with functional answers and it was apparent that many times, they were constructing without a clear reason why they were using particular materials.

Below is a transcript from a discussion between Randy, a sixth grader, and Libby, his volunteer mentor, as Randy was speculating on the re-design of their penguin house. Libby was not an engineering/science graduate student (Flip video interview 17, 11-05-09).

Randy: We...we had lots of aluminum foil. And we used this to put it on top [pointing to illustration on the storyboard], so that the cotton balls would help Penny [their penguin]. And then there was a stick to like, hold it on. And then we used like the foam for like extra layers, and um...our house improved this week.

Libby: Ok, so what do you think we can do next week, because we still didn't win.

Randy: We can have less aluminum foil...just knock it out.

Libby: Do you think less aluminum foil or less foam? Because we had a lot of foam this week that we didn't have last week. Do you think that helped or didn't help? What do you think helped the most?

Randy: It...it really didn't help.

Libby: It didn't help? And what about the tinfoil?

Randy: It was ok, but...

Libby: Maybe, well we said that tinfoil keeps the heat out, so could that have been an issue since the tinfoil wasn't covered on the inside?

Randy: Yeah.

Libby: So, what are we going to do different next week?

Randy: So, we're gonna use less foam.

Libby: Sounds good.

Although this dialogue allowed Randy to reflect on how he built his house, his reasoning on why he used specific materials was not so clear in his mind. Libby repeated something Randy mentioned earlier, that tinfoil keeps the heat out, but she did not probe his meaning around this statement. Also, she asked, "What do you think helped the most?" – a question that does not help Randy make meaning about the ways that the materials interact with heat and energy transfer.

In contrast, several of the mentors who were engineering undergraduates were able to introduce scientific terms and ask questions that required students to reflect on their design (Figure 2). Students often held naïve conceptions about how heat interacted with different material types. Understanding students' conceptions of energy transfer required the mentors to ask probing questions. Those mentors who asked, "Why are you doing that?" - were able to hear students articulate the reasoning behind their design process. These kinds of questions provided an opportunity for the mentors to integrate key terms such as convection, conduction, and insulation. Mentors were also able to push students to test their ideas or to connect their design with the observations of the materials they made before they started the construction.



Figure 2. Engineering student mentor (left) with middle school student.

Below is a transcript of a conversation between Brian, a seventh grader, and his mentor, Gary, as they were planning the re-design of their penguin house (11-05-09, Video 31).

Gary: What about the light bulb?

Brian: The light reflects on every side.

Gary: They do. Isn't that where the heat is coming from?

Brian: The light bulbs...they are reflecting, keeps...keeps...keeps. [Brian uses hand signals to indicate the generation of heat.]

Gary: That's right, so what happens? You've got radiation from those light bulbs. That's like the sun. There's two other things the website talked about, conduction and convection. Do you remember anything about that? What was conduction like?

Brian: Conduction is...an insulation...it's like electricity.

Gary: Conduction is like a pan, a frying pan on a stove. Right? It touches the stove and it gets hot. Right? What is conduction like?

Brian: What's a conduction?

Gary: That website that Robert was talking about. Conduction...where two things touch and they transfer heat.

Brian: Oh, and it's heat...hot.

Gary: Convection must be the opposite right?

Brian: It's insulating?

Gary: Convection is like when heat transfers through the air, when two things aren't touching,

Brian: Oh! Like that [he points to the heat box behind him]. So we need to build it like that, so that it will balance.

Gary: Exactly! Yeah, you want to think about convection and conduction. So, let's talk about the design of the house.

In this dialogue, Gary has re-introduced terms that Brian and Robert found on a website while constructing their blog. Through his questions, Gary realized that his teammate Brian did not understand the difference between the terms conduction and convection, and offered some real

life examples. Brian became excited when he understood what was meant by convection, pointing to the box with the heat lamps next to their table. Their re-design proceeded with Brian and his teammate Robert reconsidering their building materials, using these new words together as they debated their new design (Figure 3).



Figure 3. Brian and Robert re-constructing their penguin house.

Sequence and pacing.

Movement back and forth between the design process, the development of the storyboards, and blogging on the Moodle sites afforded time for students to reflect on how to revise their designs. The second round of re-designing the penguin houses offered students an opportunity to question their understanding of the ways that heat transferred. But rather than launching directly into the redesign and a new construction, students were asked to either work on their storyboards or to record their ideas on their Moodle website. This sequence and pacing was an important aspect of enhancing students' sense of their abilities and their accomplishments at each step of the design process.

The storyboards were not as effectively used as the Moodle websites, possibly because the storyboard format was new to the students; students didn't have a template for how to compose the storyboard or what exactly to record on the board. However, one team, with some coaching from their mentor, found the storyboard to be a place where they could record their thoughts about the design process (Figure 4).



Figure 4. Randy's storyboard.

The Moodle site was more familiar to the students, as their school used this application in its day-to-day activities. Students enjoyed the freedom of personalizing their Moodle space and choosing to record what they found interesting from each studio session or what they gleaned from other Internet websites. The older students were particularly sophisticated in terms of bringing in web content from other locations on the Internet, as well as using PowerPoint to compose a presentation at the end of the project (Figure 5).



Figure 5. Mentor working with two students on their Moodle sites.

Conclusion

Students in Studio STEM perceived that their engineering and science knowledge increased through participating in the after-school program. They found engineering much more interesting than before, and believed more in the usefulness of knowing about and learning engineering.

Their attitudes toward and perceived abilities in science and computer technologies did not improve to the same degree as their attitudes toward and perceived abilities in engineering. The mentors played a key role in helping the students increase their motivation to work through the design challenge. Engineering student mentors were most helpful in providing science and engineering support and coaching while non-engineering mentors provided encouragement and motivational support. Another key element to the success of this project was in providing students with time to reflect on their ideas. Reflection was facilitated by storyboarding, but more effectively through the online Moodle platform.

Results from this study will further the knowledge base and theory in the area of STEM education. In addition, the assessment process used to measure these constructs will be of interest in the field of educational psychology and content disciplines such as science and mathematics education.

Through their participation in the Studio STEM Save the Penguins module, students realized that better engineered houses that use less energy for heating and cooling have a positive effect on their lives and the lives of penguins. Students learned about the positive impact engineers can have on the living creatures of the world. In the process of learning the science of heat transfer and thermal energy, students also learned many technical skills and collaboration skills, which had a positive influence on students' attitudes toward science, engineering, technology, and the environment.

Given the emphasis on a participatory culture, Studio STEM not only incorporated hands-on, minds-on engineering design activities, but it also incorporated multimedia production and networking technologies as an integral part of the activities. As a sociotechnical unit, social software provided a platform to conduct the activities. Social software refers to software that allows people to connect or collaborate through computer-mediated tools.⁴⁴ The Moodle platform was used in this intervention to allow for this computer-mediated sharing and collaboration.

The implementation of the Save the Penguins curriculum in an informal setting with underserved youth in a rural community was a success in that students experienced engineering in the form of play. They came away with more positive attitudes toward engineering and asked their teachers, "When can we save more animals?"

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