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After-School Spaces: Looking for Learning in All the Right Places

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Abstract After-school settings provide youth with homework support, social outlets and fun activities, and help build self-confidence. They are safe places for forming relationships with caring adults. More after-school settings are starting to integrate Science, Technology, Engineering, and Mathematics (STEM) topics. What science skills and concepts might youth learn in *engineering design-based* after-school settings? Traditional assessments often fail to capture the ways youth learn in informal settings, and deep science understandings are notoriously difficult to measure. In this study, we examined three after-school settings where 65 youth were learning science through engineering design challenges. In this informal setting, we examined storyboards, social networking forum (SNF) chat logs, videos of whole-class interactions, interviews with groups and single participants, and traditional multiple-choice pre- and posttest results. As we looked for evidence of learning, we found that the social networking forum was rich with data. Interviews were even more informative, much more so than traditional pencil and paper multiple-choice tests. We found that different kinds of elicitation strategies adopted by site leaders and facilitators played an important role in the ways youth constructed knowledge. These elicitation strategies also helped us find evidence of learning. Based on findings, future iterations of the curricula will involve tighter integration of social networking forums, continued use of videotaped interviews for data collection, an increased focus on training site leaders and facilitators in elicitation strategies, and more open-ended pencil and paper assessments in order to facilitate the process of looking for learning.

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The structured after-school space has long demonstrated educational benefits (Gerber et al. 2001; Tamir 1990). After-school settings typically provide homework help, supporting youth to build self-confidence (Beck 1999). After-school settings provide safe places for socializing and forming relationships with caring adults (Payton et al. 2008). While there is sufficient evidence that youth may learn science through non-school *science* programs (Cantrell et al. 2006; National Research Council [NRC] 2009; Sadler et al. 2000), there is a lack of research on determining what science and engineering youth might learn in *engineering design-based* after-school settings. Ideal learning outcome measures differ between formal school settings and informal, after-school ones, and traditional academic measures may fail to capture the range of ways youth demonstrate learning in informal settings (NRC, 2009).

The purpose of this study is to understand how middle school youth learn and express science and engineering content knowledge as they participate in an engineering design-based curriculum. Rural youth were located in three after-school studio locations, guided by undergraduate facilitators from a local university, within a collaborative environment enhanced with access to a social networking forum (SNF). The collective activities will be referred to in this paper as Studio STEM. The research questions guiding the investigation are as follows:

1. What are ways to determine changes in youth's understanding of science concepts in informal, design-based settings such as Studio STEM?
2. What changes were identified in youth's understanding of science concepts, and through what form?
3. How do the actions of site leaders and facilitators influence youth's learning of science concepts?
4. How does the use of social networking forums for intentional dialogue influence youth's understandings of science in these settings?

Guided by a mixed methods framework (Creswell 2003) we attempted to identify ways in which the online discussions, face-to-face teamwork, and support of site leaders' and facilitators' words and actions helped youth with problem-solving and conceptual understanding of science. Findings suggest that the different kinds of elicitation strategies adopted by site leaders and facilitators, on-site and online, played an important role in the ways that the youth were able to engage in the design process and construct new conceptual knowledge. These elicitation strategies also played a key role in how we found evidence of learning.

Overview of the Curriculum

The curriculum used in this study, *Save the Penguins*, was developed by Schnittka (2009) and is discussed in detail in extant published work (Schnittka et al. 2010, Schnittka et al. 2012). In brief, *Save the Penguins* encourages youth to recognize how their energy consumption behaviors at home might affect penguins in the southern hemisphere. Scientists suggest that the fossil fuel energy used in houses could be linked to increased levels of carbon dioxide in the atmosphere, which in turn could have widespread effects on life on Earth, penguins being particularly affected (Gross 2005; Jenouvrier et al. 2009). When engineers design better building materials to conserve energy, and when builders use these materials, the potential for positive influence on the environment increases. This is the problem presented to youth: Given requisite knowledge of science and engineering, how would one create better dwellings at home that conserve energy to reduce the impact of CO_2 emissions on the environment? In school settings, the curriculum typically takes five 90-min class periods to complete. In this after-school setting where productive failure, freedom to tinker, and extensive dialogue are highly encouraged, the curriculum takes longer. Youth spend time talking with their facilitators, posting to a social networking forum, and storyboarding more than typically permitted in classroom settings. Youth used the social networking forum Edmodo (www.edmodo.com) to communicate with each other (within site and between sites) and the site leaders and facilitators as they worked on the project.

The site leaders first taught youth about the science of heat transfer with a focus on conduction, convection, and radiation, engaging them in activities illustrating all three methods of heat transfer. These activities were discrepant events designed to challenge youth's misconceptions and naïve conceptions about heat transfer (such as the idea that metals trap "coldness" or that "coldness" transfers). Youth were challenged to design, build, and test a small structure that would keep a penguin-shaped ice cube from melting in a heated oven. Youth worked in teams of three to four, and were provided with a small budget of play money from which to purchase available materials, which served as a design constraint. Facilitators guided youth through experiments to test each material's 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.

Theoretical Framework of the Design Studio Model

Studio STEM is an out-of-school program (with after-school and summer programming versions) designed to increase middle school youth's understanding of science, technology, and engineering through loosely structured challenges related to energy security and sustainability. The curriculum follows the philosophy of design-based science (DBS) (Fortus et al. 2004). While design is a problem-solving activity that employs cognitive reasoning, mental models, and operation within constraints (Lewis 2006), DBS activities also involve the application of science, and lead to a successfully designed artifact. The American Association for the Advancement of Science (AAAS) recommends that all students become familiar with design projects in order to engage in problem solving in real-world contexts. They recommend that:

> Perhaps the best way to become familiar with the nature of engineering and design is to do some. By participating in such activities, students should learn how to analyze situations and gather relevant information, define problems, generate and evaluate creative ideas, develop their ideas into tangible solutions, and assess and improve their solutions. (AAAS 1993, p. 48)

With DBS curriculum, the benefits of design are integrated with the benefits of inquiry-based science activities.

Youth are introduced to background information about an energy issue and its effect on an animal or ecosystem. Information is presented through the use of foundational, yet brief, lecture presentation technology with embedded video clips, audio, and images. The presentation also challenges youth to contemplate the impact of humans and human-made technologies on the planet. This treatment is meant to relate the material more strongly to youth on a personal level, which may influence their engagement with the project (Kolodner et al. 2003). Science concepts are presented in the form of hands-on experiments and demonstrations. Youth are then given the challenge of designing and constructing an artifact that helps solve the environmental problem at hand. Groups are given a limited amount of play money that they may use to purchase materials to use for construction. Through a design and redesign process, youth are given the opportunity to correct errors to improve earlier iterations of design, the iterative selection and arrangement of elements to form a whole by which individuals create artifacts, systems, and tools intended to solve a range of problems. Teaching STEM content using design is potentially a powerful way to leverage the design process. When youth identify the problem, consider their options and constraints, and then plan, model, and test multiple iterations, their higher-order thinking skills are called on to solve the problem. Design-based science engages youth as critical thinkers and problem solvers and aids in using science and technology as tools to solve problems (Honey and Kanter 2013; Ke 2014).

The studio model places emphasis on: (a) a content-rich curriculum that links youth to their environment, (b) support and scaffolded discussions with mentors (site leaders and facilitators), and (c) an online social network that supports the creation of content and maintenance of relationships among program participants. The informal, interest-driven character of this program allows youth the freedom to explore and self-identify with STEM topics unlike what is encountered in the classroom (Jonassen et al. 2003). Youth are motivated by their ability to engage in the work, influence outcomes, and contribute ideas to the solutions. Learning is accomplished in pursuit of the specific project goal as youth work through the challenges that arise (Bers et al. 2014).

The studio model works within the theoretical frameworks of social construc*tivism* and construc*tionism*. The social constructivist perspective on education stresses that students should play an active role in their own learning, work together to solve problems, discussing and debating, while cooperating at the same time. The role of the teacher should be that of a facilitator, and the teacher takes a very active role in interacting with students to find out what they know and what they are thinking. Knowledge is constructed by the individual, but mediated through social interactions with peers and the teacher in the classroom (Palinscar 1998; Tobin and Tippins 1993).

Constructionist theorists hold that learning happens best when children are engaged in creating personally meaningful objects and sharing them with their peers (Maxwell 2006). The Maker/Do It Yourself (DIY) movement with its emphasis on learning through direct experience, hands-on projects, tinkering and invention, is based on constructionist learning even if its members and advocates do not explicitly reference the theory. Advocates of learning-by-making are disposed to constructionism (Stager 2013).

The simplest definition of constructionism evokes the idea of learning-by-making and this is what was taking place when the students worked on their penguin dwellings (Papert 1991). Since the 1960s, Papert led several school-based interventions during which he and his colleagues introduced computer programming and robotics experiences for children and teachers (Stager 2013). Constructionism, like constructivism, emphasizes that learning is "building knowledge structures" and that physical structures, when built, can be things to think with (Papert and Harel 1991). Taken together, *construction*ism and *constructiv*ism lend themselves particularly well to our approach because as youth construct physical structures, they also construct knowledge structures.

Method

Participants

Youth

Sixty-five middle-school-aged youth in three after-school sites at middle schools in a rural, economically struggling region of a mid-Atlantic state in the United States participated in the project. These sites were: East Middle School, North Middle School, and South Middle School. The site leaders, who were teachers at the host schools, explained the project to the youth and provided information and consent forms to take home to their parents for final approval. Parents for all participants completed informed consent forms and all participating youth completed requisite assent forms.

Participants were recruited based on information from school principals and site leaders at each site. The site leaders worked to accept students of varying engagement levels with schoolwork and those who had access to transportation after-school since the schools did not offer after-school transportation to the STEM students. This logistic proved to be cumbersome for some students who cited their inability to participate due to the limitations of a caregiver to provide transportation.

Site Leaders

The site leaders were three females. Tina, the site leader at East Middle School was a 29-year-old 4th grade mathematics teacher with 8 years of teaching experience. Helen, a 55-year-old 5th grade science teacher with 33 years of teaching experience, was the site leader at North Middle School. The site leader at South Middle School was Joy, a 29-year-old middle school science teacher with 7 years of teaching experience. School and site leader names are pseudonyms.

The three site leaders received a full day of professional development training to implement the curriculum.

Facilitators

Undergraduate students in STEM fields from the nearest university were recruited to serve as facilitators during the experience and worked with the site leaders at each location to answer questions, assist the site leaders, and serve as experts in the curriculum. A full day of training (9 am–3 pm) took place for the facilitators a month before the after-school programs began with all the materials that the youth would be using. Facilitators who could not attend the training watched a videotape and engaged with the materials.

Training for Site Leaders and Facilitators

The professional development session for site leaders and facilitators was led by the first author (and assisted by co-authors), directing site leaders to engage with the curriculum as youth would, while providing sufficient time for discussion, reflection, and customization. Workshop participants worked in small groups (comprised of a site leader, facilitator, and principal investigators), participated in demonstrations, tested materials, designed and constructed penguin dwellings, tested these dwellings, and engaged in a redesign after discussion. Additionally, the curriculum was printed out for reference supplemented by a detailed book chapter about heat transfer. Facilitators also received a handbook discussing facilitation techniques to review and met with the project manager (aco-author) in one-on-one meetings to discuss the concepts, answer questions, and review expectations before being deployed to school sites.

Site Logistics

Though site leaders received standardized materials and training for Studio STEM, site logistics were different at each host school. In the following sections, these sites are described to situate research results in the context of where investigations on learning took place.

East Middle School East Middle School hosted 24 participants (11 boys and 13 girls). Representative of the population demographics of the region, all of the youth were White/Caucasian. Their ages ranged from 10 to 13. Individual interviews were conducted with 14 randomly selected participants (7 boys and 7 girls) at the end of the program. Twenty of the youth completed the pre- and posttests. Also representative of the socioeconomic status of residents in this region, East Middle School had 44.7 % of its students qualifying for free or reduced lunch prices at the time of the study.

East Middle School students were selected to participate in Studio STEM based on in-class engagement and performance to maintain a diversity of participants. The site leader stratified the sample by choosing students deemed low, medium, and highly engaged and also considered the academic performance of the students in their school coursework. Youth met two afternoons each week for 1 h over the course of 10 weeks. The site leader worked with the guidance counselor to make sure the youth and parents understood the research design for the program and to ensure that youth could commit to participating for the 10-week period. The administration at East Middle School was supportive of the program and the principal would often stop by to check in during program sessions.

Activities took place in the school library. The library offered open space with large tables that could be moved around to meet the needs of the program. Youth sat in their groups and were free to move about the room to get comfortable, spread out their supplies, and use the space in its entirety. Youth had access to a computer lab to access Edmodo and the Internet.

North Middle School North Middle School hosted 30 youth (19 boys and 11 girls) with one female student being African American and the remaining Caucasian. All youth participated in small group interviews at the end of the unit. Twenty five of the youth completed pre- and posttests. North Middle School had 46.6 % of its students qualifying for free or reduced lunch prices at the time of this study.

North Middle School youth self-selected to participate on a first-come, first-served basis. The site leader sent the promotional materials home with youth whom she taught and worked with the principal and other teachers to distribute the materials. The first 30 students to return the signed Institutional Review Board forms were chosen. The principal at North Middle School was supportive of the program and would often stop by to check in during program sessions. The principal worked closely with the site leader and the project associate to overcome any challenges and made other spaces available within the school for the open house at the end of the program.

Activities also took place in the school library at North Middle School. The library had large tables that could be moved around, and youth were free to move about the room to get comfortable, spread out their supplies, and use the space in its entirety. Youth had access to a computer lab to access Edmodo and the Internet.

South Middle School Eleven participants (5 boys and 6 girls) attended at South Middle School with one male student being African American and the remaining White/Caucasian. Only four boys participated in small group interviews at the end of the unit and only three youth completed the pre- and the posttests. South Middle School had 57.5 % of its students qualifying for free or reduced lunch prices at the time of this study. See Table 1 for a summary of all three sites.

Studio STEM at South Middle School differed from the other sites in that it was situated as part of the local Boys and Girls Club programming. Youth were selected on a first-come, first-served basis from within the membership of the Boys and Girls Club. Youth at South Middle School also met in the school library, which was outfitted with flexible seating, tables and chairs, comfortable lounge areas, and computer stations for youth to use. See Fig. 1 to see what the setting was like at South Middle School.

Data Collection

To address the research questions, investigators triangulated data sources. Data were collected at each of the three sites through videotaped observations, pre- and posttests on science concepts, Edmodo chat logs, hand-drawn storyboards, and transcripts of interviews conducted by studio site leaders and the research team. Triangulation of data collection allowed investigators to address issues of construct validity. Multiple sources of data provided distinct facets of the phenomenon being studied (Stake 1995; Yin 2009). See Table 2.

Observations and Video Analysis Data Whole-class studio sessions were videotaped at each location each week of the program using two cameras. A stationary camera captured the action of the entire space. A second hand held camera focused on selective close-up action at tables as youth were designing, or when youth were presenting, or at computers as youth posted to the Edmodo site. The purpose of the videotaping was to document interactions for further analysis. Observations, as defined by Rossman and Rallis (2003), included “formal, structured noting of events, activities, and speech… and participant observation” (p. 172). These methods allowed the researcher to observe the flow of the after-school setting and the interactions taking place among the site leaders, facilitators, and youth during Studio STEM. Quotes from individual youth are cited with their gender, location, and pseudonym.

Pre- and Posttest Data The pre- and posttest, *Heat Transfer Evaluation*, was administered on the first and last days of the program. This 12-item multiple-choice instrument from Schnittka and Bell (2011) has demonstrated validity and reliability with the middle-school-aged population and is designed to target common alternative conceptions that youth have about heat transfer. This instrument was used not only to determine concept attainment, but also to compare how youth in an informal, after-school environment perform on the assessment

Table 1 Studio STEM at the three sites

Site	Site leader	School discipline taught	Number of facilitators	Number of students	% Eligible for free/reduced lunch
East	Tina	Mathematics	5	24	44.7
North	Helen	Science	5	30	46.6
South	Joy	Science	5	11	57.5

Fig. 1 Studio STEM at South Middle School

compared to middle school youth in formal classroom settings. See Appendix A for a copy of the assessment.

Edmodo Chat Data Throughout the Studio STEM program, facilitators and youth were encouraged to interact through Edmodo, which provides an age-appropriate online platform for youth that can be adopted to enhance and expand on-site discussions in the after-school setting. The purpose of including access to Edmodo was to expand the on-site informal learning setting, providing youth with opportunities to continue interacting with one another and instructional materials outside of the scheduled program time (Evans et al. 2014).

Youth were given time during each program session to access Edmodo to explore and expand on the concepts introduced through the program with peers, facilitators, and principal investigators. While on Edmodo, site leaders and facilitators could scaffold discussions by posting relevant prompts. Though the site was available to youth outside of the program hours, log data showed that more discussion occurred during program time.

Storyboards As the youth proceeded week-by-week through the curriculum, they kept track of their activities and findings, ideas, and designs by generating storyboards (Kolodner et al. 2003). Youth constructed their storyboards in groups on poster paper by dividing the paper into

Table 2 Data collection

	Preinstruction	During Instruction	Postinstruction
Heat transfer evaluation	x		x
Edmodo chat logs		x	
Interviews			x
Group videos		x	
Storyboards		x	
Whole-class video		x	

sections like a comic strip, and each group filled approximately 16 squares with content over the course of the sessions. See Fig. 2 for a sample storyboard.

Interviews Exit interviews were conducted with 48 of the 65 participants, videotaped, and transcribed for analysis. The purpose was to gain further insights from a subset of youth, including youth who may not have displayed evidence of learning in traditional verbal or textual ways. To capture the "lived experience" (Corbin and Strauss 2008) of participants and their reactions to STEM content and learning, the process of interviewing provided opportunities for both formal, structured interactions with the participants, as well as informal conversation (Rossman and Rallis 2003).

Data Analysis

Observations and Video Analysis Two investigators reviewed all classroom videos, pausing every 5 min to summarize events in writing. Upon completion, the summary notes were coded to identify themes of teaching technique, use of computers, roles of facilitators, student behavior, and concepts discussed. Investigators adopted this analytical procedure to capture details about the site leader's implementation of the curriculum, questioning strategies, the nuances of the environment at the three sites, the behaviors of the youth, and the general level of engagement of the participants. While the whole-class videos did not record individual youth conversations and the finer details of group work, the effort of transcribing them resulted

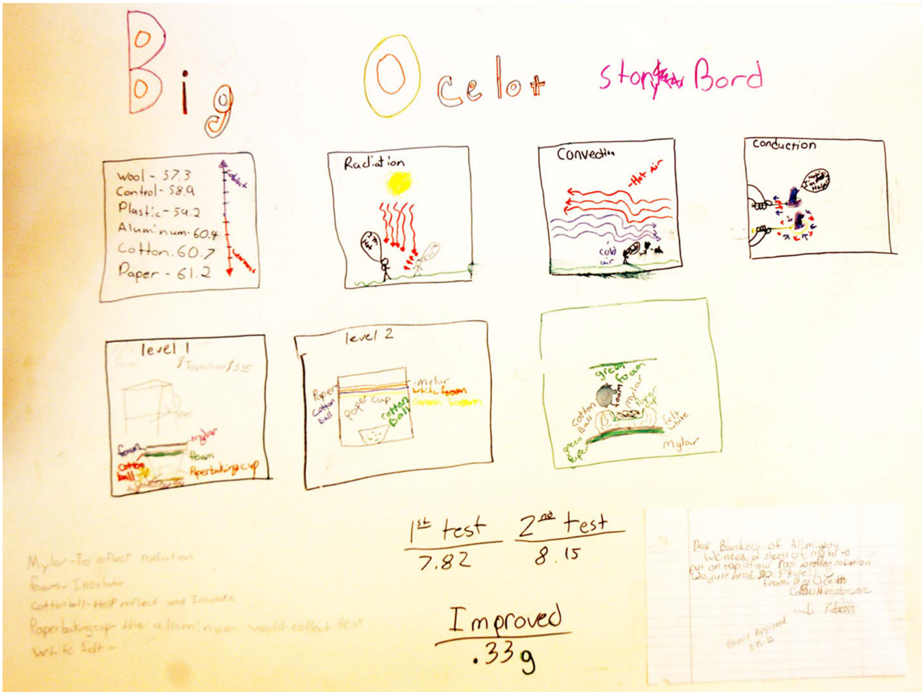

Fig. 2 Storyboard from East Middle School

in a detailed depiction of context and interaction details that might have contributed to learning.

Pre- and Posttests The pre- and posttests were analyzed using paired *t* tests and a one-way ANOVA to look for differences between groups. This analysis was used to look for evidence of science conceptual change since the instrument was designed to pinpoint youths' alternative conceptions about science concepts related to heat transfer.

Coding Procedure of Online Data Analysis of Edmodo chat data was performed using a codebook developed by the research team. The codebook was derived a priori from the HOMAGO model defined by Ito et al. (2010) to categorize student and facilitator discourse for further analysis. It included some preliminary categories and codes that were meant to provide guidance in the form of focus areas. The codebook was tested using Edmodo data from an earlier iteration of Studio STEM. Following testing, the research team made changes to the original codebook in order to better capture the emergent themes. This iterative, flexible adjustment of the codebook has been described by Fonteyn et al. (2008) as a way to account for new themes and ideas throughout data analysis. The third iteration of the codebook, developed from the first pass through the current data set, became the working version.

Development of the codebook emphasized the action-oriented nature of language in which discourse is undertaken to serve a particular purpose (Roth 2007). Here, analysis of talk through Edmodo was based on an attempt to understand the motivation behind youth posting as it related to Studio STEM. For example, youth might post for the purpose of increasing social interaction with peers involved in the program. They might also post for the purpose of asking questions or clarifying concepts discussed in the STEM curriculum. In this way, youth might utilize Edmodo as a way to articulate their understanding, allowing for feedback and discussion. The analytical posture compels one not to assume the talk is merely the reproduction of a priori constructs in the head. Meaning is made through active engagement with peers through social media (Clegg et al. 2013).

Transcripts of site leader, facilitator, and youth posts on the Edmodo site were analyzed. Codes ranged from *hanging out* (HO) (discussing favorite foods and pop icons) to *geeking out* (GO) (engaging in sophisticated discussions on science and engineering problems and solutions), to *messing around* (MA) (informally seeking information). Though *geeking out* might strike one as having negative connotations, in the framework of Ito et al. (2010), it is meant to convey positively that youth are developing levels of expertise that are recognized and valued by immediate peers.

These genres of participation indicate how youth transitioned from friendship-driven to interest-driven interactions for intentional learning. Again, the *geeking out* genre indicates that one has taken ownership of the content and is being recognized as an expert in a community of likeminded peers, capitalizing on the affordances of SNFs to build and disseminate this valued knowledge. The genres describe levels of interest, which we see as an integral part of this learning process. Youth, when allowed to use social media for academic use that was initially assigned to recreational use, often exhibit a degree of intentionality that leads to conceptual change and learning (Ahn et al. 2013). The reported results contribute to the literature on the ways youth productively adopt social media for intentional learning in free-choice environments (Evans & Jones 2012; Hung et al. 2012).

The HOMAGO framework is descriptive in nature: its use was to identify forms of participation through technology as we looked for learning in the context of socially mediated activities. Originally created to describe the ways that youth engage with technology, our use of the framework to analyze data on social media is unique.

Before the beginning of each program session, a graduate research assistant (aco-author) was responsible for collecting chat logs, which had sometimes been submitted outside of the studio time over the course of the preceding week. All postings were read thoroughly, and quotes relevant to the project were sorted and analyzed. More on the sorting technique associated with thematic coding protocols can be found in Fereday and Muir-Cochrane (2006) and Fonteyn et al. (2008).

Storyboards The storyboards were analyzed to identify evidence of learning, evidence of lingering misconceptions, and evidence of science concepts applied to the engineering design task. Text that was dictated to youth by the site leaders was ignored. Instead, drawings, designs, ideas, and other spontaneous evidence of learning were examined and analyzed.

Interviews Exit interview analysis was directed at looking for evidence of learning science and engineering, evidence of misconceptions about science, and attitudes toward science and engineering. One researcher (lead author) and a graduate student reviewed the interviews, created the transcriptions, and coded the transcripts for evidence of learning and evidence of attitudes. The researcher and graduate student discussed their separate findings and interpretations until they were in 100 % agreement about the findings. See Appendix B for interview questions.

Results and Discussion

Video Analysis

East Middle School The site leader at East Middle School began each session by reviewing material from the previous session, asking questions to help the youth recall information, and used technology aides such as a computer and projector to assist with the overview. She would then give the youth their tasks for the day and follow with a demonstration or the youth would begin their work. The facilitators mingled among the groups, asking more questions, helping youth figure out their task, or observing. The site leader would check in with the youth by giving time prompts or asking if there were any questions. Sessions usually finished with entering details on a storyboard, posting to Edmodo, or cleaning up the space.

Based on whole-class video, it was evident that this was a teacher-centered environment during pointed periods each week, the site leader using an elicitation-and-response format during whole-class discussion. For example, she might ask, "…which means it rises to the…. ______ and the cold stuff sinks to the bottom… and that is ________." She was not overly focused on definitions and gave the youth ample time to freely discuss concepts amongst themselves, and asked probing questions to determine why youth were choosing certain materials or placing materials in a specific location. The site leader had youth present designs and findings each week once the design and testing phases began, and regularly interjected questions during these presentations, stressing that they were all trying to learn together. The site leader offered additional funds for purchasing supplies based on the quality of the storyboard, an incentive to document experimental and design details carefully.

Videotaped interviews were conducted with 14 of the 24 youth at the conclusion of the unit, and through the analysis of these videos, assumptions could be made about the science and engineering learning that took place. Most of the youth understood that the design of the house should have less surface area to reduce heat transfer into the house, but they did not always articulate why. One student said it kept down costs: "A rounded surface has less surface area so we could use the materials more thickly with it costing less" (Male, East MS, John). Most of the youth identified that Mylar and aluminum foil reflect light, thereby reducing radiation. Nevertheless, some said it reflected heat. While it is true that reflective surfaces reflect infrared radiation (heat), this was not explicitly taught and might have been the articulation of a prior concept. For example, "We used the Mylar and foam and aluminum to reflect the radiationa" (Male, East MS, Lyle). Most of the youth recognized cotton, paper, and felt as insulators. For example, "We used insulation so none of the heat could get in. We used foam, bubble wrap, and a cotton ball" (Female, East MS, Ninah). A few of the youth used glue or paper to block holes to reduce heat getting into the house, but they did not articulate that they were preventing convection. For example, "We used glue to make it air tight so none of the heat would seep in" (Female, East MS, Chrissy). Most of the youth struggled with clearly identifying the mechanisms of heat transfer (i.e., radiation, conduction, and convection) underlying the construction of their penguin houses. Most of the youth used Popsicle sticks to hold (or position) the house, which was not a wise use of limited funds since other, less expensive materials could be modified for structural purposes.

There were some lingering misconceptions, such as the misconception that air is a poor insulator. For example, "We minimized the amount of air because air isn't a good insulator" (Male, East MS, John) or the misconception that black materials are conductors: "We used two black sheets to conduct heat" (Male, East MS, Chum).

North Middle School At North Middle School, the site leader began each session by encouraging youth to get a snack and would often display a question on the interactive whiteboard to help youth recall what they had done in the previous session. While the youth were eating, the site leader would review events from the previous session and probe prior knowledge on upcoming content. Youth would break into their groups to receive instruction on the tasks for the day. Youth would work for the majority of the session and finish the session by revising storyboards, posting entries on Edmodo, and packing up materials from the session.

Based on whole-class video, it was evident that the teacher focused on definitions and diverted from the curriculum-as-written to add in her own activities, which may have added confusion and reduced youth interest. For example, on the first day of the unit she was teaching the definitions of heat and temperature. She stressed the correct documentation of the definitions on the storyboards, and corrected youth when they were wrong even on the second day of the unit. She was still stressing the definitions of heat and temperature on the third day of the unit even though specific definitions are not explicitly referenced in the curriculum. Evidence of learning, consequently, in the whole-class format was less evident than in small groups.

Based on exit interviews with groups of youth, there was a clear lack of some key understandings at the end of the program even though definitions had been emphasized throughout the unit. Some youth could not easily associate the materials used in building their penguin dwellings with the kind of heat transfer they counter. For example, "We had a lot of stuff like foam, bubble wrap, and felt on top sandwiched to keep radiation, and Mylar on top to help with that" (5 males in Team A, North MS). There was an emphasis on structure instead of heat transfer. For example, "We used the materials for the penguin house so that the house is steady and don't break" (4 females in Team P, North MS). Some youth did not articulate themselves clearly in the exit interviews, and some youth did not pay considerable attention to the project. There were examples where youth clearly did not understand the objective, for example, "The roof shades the floor. It keeps the radiation from hitting the black floor" (4 males in Team C, North MS).

Nevertheless, most of the youth considered the cost of materials used to build the penguin dwelling. They reduced cost by building smaller penguin structures. The budget may have played too large a role in the design, for example, “Money is really important because we were almost out” (5 females in Team S, North MS) or “We made the house smaller and put an umbrella on top” (3 males in Team B, North MS).

South Middle School Due to an emphasis on sports and remediation activities in the Club, a greater degree of attrition and lower regular attendance at South Middle School was evident. Youth would often attend Studio STEM one week but not the next. Due to low and sporadic attendance, it was difficult for the site leader to deliver the content and difficult for the facilitators since youth were at varying places in the curriculum each week. This situation may have contributed to lower learning gains at this site. However, youth at this site also met less frequently than youth at the other two sites: once per week for 90 min for 7 weeks. It is likely that the combination of sporadic attendance and reduced time with the curriculum negatively affected learning outcomes.

The site leader began the sessions by tracking down youth and would send another student in attendance to find missing youth, depleting precious time allocated to the program. The site leader would begin with an extensive review of the previous week to help youth get back on track and catch up the youth who had missed the previous week. Youth worked in pairs with a facilitator to complete the tasks and demonstrations. Youth finished each session with storyboarding and time to answer questions on Edmodo. Youth would leave early, sometimes asking for permission. South Middle School had enough computer workstations in the library for youth to access.

Based on the whole-class video, youth and site leaders at South Middle School had a relaxed, informal attitude about the curriculum. The atmosphere was playful and the discussion frequently got off topic. There were few examples of direct instruction, and few examples of interpretive discussions. In general, there was a lack of focus on the part of the youth and the adults. Youth at South Middle School demonstrated a detectable lack of deep understanding of the science covered while describing in interviews the design decisions they had made about the penguin houses. The three methods of heat transfer were not well understood. For example, one male student said, “Well, we figure out Mylar and cotton works the best to keep the house cool” (Male, South MS, Tyler). Another said, “The felt is to keep heat from getting to the penguin” (Male, South MS, Bryan) and a female student said, “We put white felt so that it could protect the penguin” (Female, South MS, Amy). The rationale for design decisions was not related to scientific evidence. For example, “We put cotton balls inside because it worked best” (Male, South MS, Folsom) or “White foam will not conduct the penguin so it won’t burn it” (Male, South MS, Tyler).

South Middle School was able to allocate only half the amount of time to the project as the other two sites—11.5 h compared to 20 h at each of the other sites. This was due to competing after-school activities, which interfered with the commitment from the school and the Boys and Girls Club. The absence of consistency of the program led to less time available to engage with the curriculum, more time being dedicated to disciplining youth, finding them to participate, and reviewing past topics to allow for consistency and progress. North and East Middle Schools were able to spend more time probing for understanding, asking higher-order thinking questions, and allowing students to build and redesign their penguin dwellings in order to form their own knowledge.

Similarities Between East and North Middle Schools Although participant recruitment differed at these two sites due to administrative preferences, the youth at East and North Middle Schools had consistent attendance records. Youth would often inform the site leader in advance if they were going to miss a given session. The site leaders stressed to youth the value of the opportunity and to take seriously the program goals. The site leaders at East and North worked closely with the Instructional Technology Resource Teacher (ITRT) to set up Edmodo accounts, teach youth how to use Edmodo, and support site leaders with the technology aspects of the program. The ITRT served the East and North sites, having to split time on days the program overlapped.

Parents, administrators, and community members were invited to East and North Middle Schools at the end of the semester for an open house. Youth presented their designs, described the design process, and answered questions from the audience. The open house served as a way to bring closure to the program and to highlight the youths' work during the previous weeks. The Superintendent of Schools, local business and industry people, and other interested community members attended.

Pre- and Posttest Analysis

The 12-item multiple-choice instrument, *Heat Transfer Evaluation* (see Appendix A), was used to assess conceptions about heat transfer before and after the unit. This instrument has been found to be valid and reliable with 8th grade students in prior studies, with students typically scoring 4 points on the pretest and 8 points on the posttest when instructed with the curriculum in a school setting (Schnittka 2009, Schnittka & Bell, 2011). The topics tested were *directionality of heat transfer* (items 1, 2, and 5), *insulators* (items 3 and 9), *radiation* (items 6 and 12), *what generates heat?* (item 4), *material properties* (item 11), *conduction* (items 7 and 10), and *convection* (item 8).

Twenty out of 24 East Middle School youth took both the pre- and posttests. There were positive changes seen in items representing directionality, insulators, and material properties. There was no change seen in the concepts of conduction, convection, or radiation.

Twenty five out of 30 youth at North Middle School took both tests. There was moderate positive change in understandings about directionality and insulators, and little to no change in concepts of conduction, convection, radiation, and material properties.

Three out of 11 youth at South Middle School took both tests. All three youth scored correctly on the posttest on one item about conduction and one item about radiation. Otherwise, there was no change in any other concepts. See Table 3 for data.

Eliminating South Middle School from the analysis due to small sample size, an ANOVA demonstrated no significant difference overall between outcomes at East and North Middle Schools, with statistically equivalent pretest scores ($p=0.84$) and statistically equivalent posttest scores ($p=0.56$).

Edmodo Chat

Twenty-three percent of Edmodo posts discussed concepts specifically related to the STEM curriculum, 32 % had a social focus, 22 % were concerned with house design and construction,

Table 3 Content test data

	Number	Pretest	Posttest	Sig.
East Middle School	20	4.75	7.3	$p<0.001$
North Middle School	25	4.64	6.88	$p<0.001$
South Middle School	3	4.33	4.66	$p=0.667$

and 23 % were opinions about the program itself. There were 640 posts in 199 conversation threads.

A natural progression in Edmodo usage was observed in youth postings at East Middle School, based on the activities and concepts presented in each session. For example, the first day of the program was dedicated to setting up Edmodo accounts and completing a pretest to assess prior knowledge of heat transfer concepts. Youth were not given instruction on any of the materials related to the course, and as a result, the vast majority of posts were coded into the *hanging out* category. An example is, “Is anyone having a good time..... anyone?” coded into the *virtual co-presence* subcode on the first day of the program. In contrast, on the first penguin house construction day, youth were prompted with a question and were able to respond with more posts that were coded into the *geeking out* category. An example here is, “Ours bc we put an insulator inside,” which was also a *STEM talk* coded post in response to the question, “Who thinks their house is going to be the best at ‘saving the penguin?’ Why???” The participant uses the word “insulator” to provide a reason for the potential success of their design. One could infer that youth possessed greater contextual knowledge (provided through the PowerPoint lecture and hands-on experiments) at this point in the curriculum.

There were few Edmodo posts made outside of the after-school environment, perhaps due to competing activities and interests capturing youth attention at home. Nevertheless, this does not necessarily mean that there was a lack of understanding or engagement with science concepts. While youth may not have been engaged with Edmodo outside of the learning environment, they appeared actively engaged with the technology when they were given time to do so. The number of posts that were created outside of the sessions was very low (very little data), so the role of the presence of the teacher was probably important in motivating students to discuss concepts.

An example can be found in the following discourse. All responses were completed on the same day as the first prompting question:

> Tina (East M.S. Site Leader) - Why do you think your penguin ice cube melted the way it did under the lights? What will you do differently in the re-build?
> B.F. - we are going to put white felt around it and some cotton balls
> S.S. - um......probably put more Mylar or more light colored material or alum. foil
> B.R. - The Arctic Power Pengiuns are going i think we have not talk about it but i think that we are going to more bubble wrap in side of the house and out side
> S.S. - good idea B.R.
> B.R. - I agree with your group S.S., our group is going to put mylar and some more bubble wrap

When facilitators asked questions directly related to the material (e.g., “What materials will you use to re-design your house?”), youth were much more likely to respond with postings that could be categorized as *messing around* or *geeking out*, indicative of higher engagement with specific concepts. This was also dependent on whether facilitation posts were created during the scheduled Edmodo time, or whether they were created after the sessions had ended. Youth were encouraged to log on to Edmodo outside of the sessions, with facilitation posts being used as a way to further extend the informal learning environment already established. This is not to say that youth did not engage in STEM talk without facilitation, but just that the frequency of STEM talk, whether accurate or indicative of misconception, was much higher with prompting. A good example is this particular collection of posts:

> Tina (East M.S. Site Leader) - Which material was a better insulator and why?
> Gina (Female, East MS) – Wool, because it keeps the warm air out!

Hugh (Male, East MS) – wool, it was very thick to keep the cold in and the heat out.
Franny (Female, East MS) – Wool i cant rember why
Brylie (Female, East MS) - it was the wool sock because it was filled in air and the heat couln't move inside to make the soda cold
Amy (Female, East MS) - it was the wool sock because it was the best isalator and kept the cool in better
Sarah (Female, East MS) - wool because it had a good amount of air in the sock for it to be a good insulator

From this example, it could be inferred that facilitation results in responses by participants. Though this sample was taken from earlier in the curriculum (misconceptions such as the ability of "coldness" to transfer are still common), youth are seen to begin to understand and articulate concepts such as insulation and the ability of heat to transfer.

While youth were seen to engage in all three areas of the HOMAGO heuristic (*hanging out, messing around,* and *geeking out*), one should not anticipate, nor proscribe, a linear progression through the analytical framework. Participants often shifted the way in which they interacted through Edmodo, from post-to-post or between program sessions. For example, a participant might create a post asking for opinions on their new profile picture (coded as *hanging out*), shortly after responding to a peer's question about the nature of conduction (coded as *geeking out*). Another participant might compare their penguin dwelling design with another team (coded as *messing around*), and then move on to posting a picture of their favorite book (coded as *hanging out*). These occurrences suggest that the HOMAGO framework provides a means to track the fluid, sometimes redundant, transitions and translations youth make as they interact in a social network forum. The ease with which they switch linguistic codes could denote a degree of comfort that is indicative of informal, yet intentional, learning that is supported by media and tools capitalizing on interest (Lai et al. 2013).

Storyboards

East Middle School Storyboard analysis from East Middle School revealed that youth were given permission to draw freely and express themselves and the ideas discussed from the curriculum in multiple formats. Youth were encouraged to draw what they thought were examples of convection, conduction, heat transfer, and radiation. All groups at East MS had unique drawings mixed with text or longer explanations of science concepts. Storyboards contained a plethora of information, from drawings to results of materials testing. Based on the volume of data recorded on the storyboards, youth were using them to record data throughout each session and not just when prompted. Youth drew pictures of penguins and other artifacts that related to the project as well as stapling other data they had collected to the storyboard, such as their grant applications for funds to purchase extra materials. Youth recorded their design ideas from phase one to phase two of the design process of their penguin dwelling.

North Middle School Youth at North M.S. had text heavy storyboards with numerous pages of results and other data taped or stapled to them to depict testing and handouts from the curriculum. The site leader included a picture of the team members to help identify youth in each group. Youth shared pictures with written descriptions of convection, conduction, heat transfer, and radiation. Youth used the storyboards extensively, recording data at each phase of the curriculum and included drawings of their first and second penguin house designs. Based on the volume of data, the storyboard appeared to serve as a living journal and was being used throughout each session.

Both East MS and North MS were consistent in their heavy use and journaling on the storyboard, and the recorded data indicated that youth had ready access to the storyboards and were encouraged to use them regularly. Youth appeared to use a mix of drawings and text to help communicate what they would need to save their penguin. Youth at both of these sites utilized drawings to show their creative agency and thought in designing their penguin houses. Youth at both sites also documented data after the testing phase of house design. Youth recorded how much mass their ice cube penguin lost on their storyboards. They tried to use identifying symbols or color-coded their storyboards to signify when something was "cold" by using a specific color marker or "hot" by using another. Youth were creative and tried to use waves or squiggly lines to depict heat moving from one place to another.

South Middle School Storyboards at South M.S. were less consistently utilized, and displayed gaps in youth's recorded data. Initially, youth used the storyboards to communicate the main ideas of the curriculum, but use slowed steadily. Some groups stopped using the storyboard at the materials testing stage and did not record additional data while other groups used the storyboard to record drawings of what the penguin dwelling looked like in the testing phase under the lights. Only one group had data on the results of their penguin dwelling testing and color-coded their storyboard to make the marker color, blue, depict that something was cold.

Research Questions Revisited

In the informal after-school setting where youth were engaged in the engineering design process, applying science concepts to design decisions, several methods were used to infer changes in youths' scientific understandings. We examined storyboards, Edmodo chat logs, videos of whole-class interactions, and interviews with groups and single participants, and administered a traditional pre-post assessment.

Results indicate that Studio STEM did have an effect on student understanding of heat transfer concepts at sites where attendance was regular. This is consistent with previous literature highlighting the effectiveness of informal extracurricular science programs in promoting science understanding among middle-school-aged youth (Cantrell et al. 2006; Sadler et al. 2000). Responses by youth often included scientific terminology introduced through the curriculum, and were often accurate. There were also a larger number of posts and comments related directly to STEM material once participants had been exposed to the lessons on heat transfer and engineering. Posts and discussions prior to the more interactive program sessions were unrelated to the curriculum, and exhibited traits related to socialization. Together, these findings indicate that involvement with Studio STEM increased student knowledge and interest in heat transfer concepts and application resulting in more STEM-related discussion.

Previous research has shown that the presence of well-defined goals helps to engage youth interest and interaction with science challenges (Sadler et al. 2000). The curriculum used in Studio STEM also provided a well-defined goal (to save the penguins through constructing an enclosure), and appeared to have a positive effect on participant knowledge and interest in science. While misconceptions were still evident at points throughout the program, this could be attributed to individual participant variation, and not the way in which the program was implemented. Youth engagement with the material was strong throughout the program as indicated through positive posts to the Edmodo website and video analysis. Pre- and posttests of science content demonstrated significant gains for youth at North and East Middle Schools.

While the pre- and posttests were valuable in determining changes in understanding over time, the whole-class observations did not shed much light on the youths' learning progress, primarily due to the inability of the camera to be everywhere at once, and the inability of the camera's microphone to pick up all of the small group discussions. The small group and individual interviews, while the most time-consuming sources of data to collect and analyze, were the richest sources for determining what youth were thinking and learning, and how they were making sense of the science and engineering at hand.

The actions of the site leaders and facilitators seemed to be key aspects in impacting youth learning. While site leaders tended toward a school-like teacher-centric didactic style of teaching, they did incorporate elements of Socratic questioning, probing for reasoning, and allowed for ample free time to explore, design, test, and re-design. Even when the site leaders focused on definitions and facts, and used a elicitation-and-response style, the freedom given to youth in the space seemed to positively impact overall understanding.

Through a thorough analysis of all the data sources available, we suggest that the social networking form played a positive role in giving the youth "voice" to express themselves to each other and to the site leaders and facilitators. The site leaders made a point to allow youth weekly access to the Edmodo site, and the youth used the site to not only talk with each other and the site leaders and facilitators, but to post websites and videos they had located relevant to the topic. As depicted above, youth were able to leverage Edmodo to learning intentionally about heat transfer while sourcing others' ideas to improve iterations of their penguin dwelling designs. Results corroborate extant literature on the ways that social and other popular media are appropriated by youth to demonstrate knowledge and expertise in purposeful ways (Clegg et al. 2013; Evans & Beidler 2012). Additionally, we noticed that with females from both North and East Middle Schools combined, and males from both schools combined (since both schools were statistically equivalent), results indicate that gender influenced the pretest scores. Female youth performed significantly poorer ($p = 0.0012$) compared to the male youth on the pretest. However, the implementation of the curriculum seemed to improve the comprehension of the intended scientific concepts by female youth because their posttest scores were statistically equivalent to those of the male youth ($p = 0.29$) (Table 4).

Conclusion

When investigators looked in the right places, evidence of learning could be found. The relaxed setting youth experienced in Studio STEM was indeed conducive to learning, but only when attendance was regular. When mediated by the support of adult volunteer facilitators who offered ideas, focused excess energy, and challenged the youth to think deeply, this impact was more evident. Youth in the studio settings were able to apply the new knowledge they gained to engineering design activities, and demonstrated that knowledge through face-to-face discourse, chatting online, drawing, and presenting. Inconsistent attendance made it difficult for the site leader at South MS to maintain momentum with the program, losing opportunities to take advantage of the curriculum, social networking forum, and time for tinkering and exploration as evidenced at the other two sites.

Table 4 Gender effect

Gender	Pretest	Posttest
Male (N=24)	5.46	7.42
Female (N=22)	3.81	6.67
P values	0.0012	0.2885

Limitations

The major limitation of this study was that this was the first time Studio STEM was carried out at three sites simultaneously. Two of the site leaders were new to the program, and researchers were juggling multiple logistical challenges related to delivering volunteer facilitators to remote locations several times a week, capturing and storing and accessing vast quantities of video data, and managing time. East and North Middle Schools were more organized overall, with a supportive ITRT (technology person) to help students with Edmodo, the site leaders were better prepared for each session, having reviewed the curriculum and prepared materials, and the students knew their expectation to attend was anticipated for each session. These factors contributed to maximizing of time dedicated to each session, allowing East and North Middle Schools to take full advantage of the after-school setting. As researchers were "looking for learning" in the youth, they were learning important lessons themselves. These lessons have contributed to the success of ongoing, new curriculum interventions in the same three sites for Studio STEM.

Future Research Ideas

This study has prompted several ideas for future research. One question is whether explicit prompting by facilitators will generate dialogue that allows us to find otherwise hidden evidence of learning. Another idea for research involves an exploration of why participants do not spend time interacting through Edmodo outside of the time scheduled for Studio STEM. Social networking forums are meant to serve as a means to extend the informal learning environment beyond the school and time dedicated to the program alone, and dialogue on Edmodo is one source of evidence as we look for learning. Understanding why participants do not post to Edmodo between program sessions might provide valuable insights into improvements for program implementation in the future.

Implications

This study has implications for how informal, design-based, youth-led STEM programs could be integrated after-school to reinforce school curricula while providing safe, secure, social outlets for development. It also has implications for how learning through design-based projects can be assessed in formal or informal settings through interviews, documented online chatting, storyboarding, and small group video analysis. Informal learning environments may serve as entry points in sustained science learning that promote voluntary and differentiated learning experiences.

Implications for integrating this informal model into a formal school day could include taking the existing curriculum and pairing it with what teachers are already teaching to find natural ties where the curriculum could be used. Adapting the lessons may be a helpful tool and offering suggestions embedded in the curriculum as to what pieces or portions fit well together could highlight the key aspects may be helpful to a formal educator. Partner or team teaching could be used across multiple subject areas to integrate as much of the curricula as possible and to teach students that one subject during school can encompass multiple disciplines. By understanding the features of this particular curriculum that successfully spurred on participants, teachers can begin to make decisions in their own classrooms that will have an impact on participants' interest in STEM subjects.

Future Implementation Ideas

Data from implementing *Save the Penguins* at three sites suggest that more time for tinkering, systematic facilitation, and broader access to social networking forums are key areas to focus on in current and future iterations of Studio STEM. In particular, scheduled time (either during the program or other informal locations) is necessary to allow for more expressive activities with the Edmodo forums. Time spent on activities and consistent attendance are major limiting factors associated with the curriculum, and should be accounted for if more effective data collection is to occur. Facilitation also appears to be an important factor in stimulating discussion and conversation among participants on Edmodo.

A critical outcome of this research is the way in which we are rethinking the structure of the after-school studio setting. With inconsistent attendance and the goal of creating an informal setting different from the school day, we are beginning to conceptualize a space which allows for more free choice and self-directed learning along the lines of what is happening in science museums as "maker spaces" are created (Evans et al. 2014). The challenge of looking for learning in after-school spaces will still be present, but perhaps there will be more learning to find. Next steps include redesigning the curriculum so that it is less linear, involves more "tinker time" and play, and integrates self-guided learning through interactive tablets. Tablets with cameras would allow for the melding of social networking through Edmodo, finding information via the Internet, video and photo uploading and sharing, and content delivery through pre-recorded, just-in-time lecture-lessons.

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Appendix A

Heat Transfer Evaluation

1. You pick up a can of soda off of the countertop. The countertop underneath the can feels colder than the rest of the counter. Which explanation do you think is the best?

   a. The cold has been transferred from the soda to the counter.
   b. There is no heat energy left in the counter beneath the can.
   c. Some heat has been transferred from the counter to the soda.
   d. The heat beneath the can moves away into other parts of the countertop.

2. After cooking an egg in boiling water, you cool the egg by putting it into a bowl of cold water. Which of the following explains the egg's cooling process?

   a. Temperature is transferred from the egg to the water.
   b. Cold moves from the water into the egg.
   c. Energy is transferred from the water to the egg.
   d. Energy is transferred from the egg to the water.

3. Why do we wear sweaters in cold weather?

    a. To keep cold out.
    b. To generate heat.
    c. To reduce heat loss.
    d. All of the above.

4. Amy wraps her dolls in blankets but can't understand why they don't warm up. Why don't they warm up?

    a. The blankets she uses are probably poor insulators.
    b. The blankets she uses are probably poor conductors.
    c. The dolls are made of materials which don't hold heat well.
    d. None of the above.

5. As water in a freezer turns into ice,

    a. the water absorbs energy from the air in the freezer.
    b. the water absorbs the coldness from the air in the freezer.
    c. the freezer air absorbs heat from the water.
    d. the water neither absorbs nor releases energy.

6. On a warm sunny day, you will feel cooler wearing light colored clothes because they

    a. reflect more radiation.
    b. prevent sweating.
    c. are not as heavy as dark clothes.
    d. let more air in.

7. If you put a metal spoon and a wooden spoon into a pot of boiling water, one will become too hot to touch. Why?

    a. Metals conduct heat better than wood.
    b. Wood conducts heat better than metals.
    c. Metals pull in heat because heat is attracted to metals.
    d. Wood isn't as strong as metals.

8. On a hot day, the upstairs rooms in a house are usually hotter than the downstairs rooms. Why?

    a. Cool air is less dense than hot air.
    b. Warm air rises and cool air sinks.
    c. The upstairs rooms are closer to the sun.
    d. Heat rises.

9. You have a can of soda in your lunchbox that you want to keep cold. Which material will work best to keep it cold?

a. Aluminum foil wrapped around the soda because metals transfer heat energy easily.
b. A paper towel wrapped around the soda because paper soaks up the moisture.
c. Wax paper wrapped around the soda because wax paper traps the moisture.
d. Your wool sweater wrapped around the soda because wool traps air.

10. When you hold a metal coat hanger in a camp fire to roast a marshmallow, the coat hanger might get too hot to hold. Why might the coat hanger get too hot?

a. The heat radiates along the coat hanger.
b. The heat builds up near the flame until it can't hold it anymore and then moves along the coat hanger.
c. Metal atoms vibrate with more energy when they get hot, and they collide with atoms near them, which makes the neighboring atoms vibrate too.
d. Since metals melt in fire, they react very strongly to fire and get hot easily.

11. An aluminum plate and a plastic plate have been in the freezer all night long. When you remove them the next morning,

a. The plates have the same temperature.
b. The plastic plate has a higher temperature.
c. The plastic plate has a lower temperature.
d. The aluminum plate has a lower temperature.

12. When placed in direct sunlight, which object will absorb the most radiation?

a. A white sweater.
b. A snowball.
c. Some aluminum foil.
d. A black sweater.

Appendix B

Exit Interview Questions

1. Explain to me why you designed the penguin house as you did, and why you chose the materials you used?
2. Was there anything else really important to you while you designed your penguin house?
3. Anything else important?
4. Anything else you want to say?

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