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Abstract

This paper describes the journey of a group of university students as they worked with underserved middle school students as mentors in a STEM-based afterschool program. Design thinking provided a frame within which students learned how to be mentors, how to create user-centered learning experiences, and how to share their experiences as developing STEM professionals with middle school students.

Keywords: STEM education, middle school learning, design thinking, mentorship, STEM careers

Introduction

The classroom was filled with the sounds of middle school students at work. There was laughter and arguments as they sketched, cut, and glued together pipe cleaners, cardboard, and popsicle sticks. They were working with university students who were taking a class that highlighted design thinking, STEM learning, and mentorship. Their design challenge that afternoon was "Designing the Ideal Room."

The middle schoolers began to work in pairs to interview their partners. They were looking to uncover stories about their partners' experiences, which would be the basis of their design.

"What do you dislike about your current room?"
"What kinds of things do you like to do in your room?"
"What is your favorite color?"
"How much of your after school time do you like to spend with your friends vs. being alone?"

The students listened with care to their partners' stories – they were developing empathy skills. Once they figured out what their partners needed, they brainstormed over fifty potential solutions to meet that need. Ideas flowed quickly for some students; others struggled. Each student chose one idea to build a low-resolution prototype. The prototypes weren't models; instead, they were spaces to interact with. Cardboard boxes, chairs, upended desks, and post-its were used as the students "built to think."

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One student, Javier, said "You have to think about the space, AND the person who is in it." "Yes," replied Annalee, "It doesn't matter what I want, it's all about my partner." The importance of understanding others' needs was an essential first step in the students' design thinking journey.

Design thinking is an innovative, human-centered approach to defining and solving complex problems. As Javier stated, a focus on the person you are designing solutions for is essential. The process engenders a sense of creative confidence that is both resilient and highly optimistic. David Kelley, founder of design consultancy IDEO and Stanford's Hasso Plattner Institute of Design, says, "My contribution is to teach as many people as I can to use both sides of their brain, so that for every problem, every decision in their lives, they consider creative as well as analytical solutions. This model, which has energized business innovation, is being applied to education with considerable impact" (Carroll, M., Goldman, S., Britos, L., Koh, J., & Royalty, A., 2010.) With its central emphasis on human needs, design thinking refocuses curriculum and assessment and forefronts solving real-world problems. According to the *Partnership for 21st Century Skills* (www.p21.org), a focus on innovation, creativity, critical thinking, problem solving, communication, and collaboration is essential to prepare students for the future. Design thinking can help one imagine new possibilities for learning that will change the lives of both teachers and students in powerful ways to build communities of 21st century learners.

Background

This paper describes the journey of a group of university students as they worked with underserved middle school students as mentors in the STEM-based Diamond Afterschool Program. The inspiration for the project was Design for the Other 90%, a themed exhibition at the Smithsonian Institution's Cooper Hewitt National Design Museum that focused on design solutions created by engineers, designers, scientists, technologists, architects, and mathematicians to meet the most basic needs of the 90% of the world's population not traditionally served by professional designers. The university researchers who designed the three-year project choose three elements of Design for the Other 90% project to build the program on: water, energy, and shelter.

The overall goal of the project was to extend the knowledge base that contributes to an improved understanding of the role of design thinking in K-12 education, issues surrounding the STEM pipeline, and the development of a mentoring relationship. One critical component of the project was a course called Educating Young STEM Thinkers. The course was open to any Whitfield University undergraduate or graduate student. In the course Whitfield students explored design thinking and issues surrounding STEM as they created activities for middle school students in the Diamond Afterschool Program. The topic for the first year of the course was water. Years 2 and 3 will focus on energy and shelter. This work was funded by a grant from the National Science Foundation.

The overall project goals in working with middle schoolers were:

1. to provide students with pathways into STEM careers.
2. to introduce design thinking as a 21st century learning approach.
3. to introduce the work that engineers, tech developers, and scientists do, and the technologies that are used.
4. to introduce the academic work the university students were engaged in.
5. to provide role models.
6. to develop mentoring relationships.

The findings presented in this paper are grounded in a four-month ethnographic study of the Diamond Afterschool Program and highlight learnings about the intersection of design thinking, STEM learning, and mentorship.

Theoretical Rationale

In order to explore more fully the intersection of design thinking, STEM learning, and mentorship, it is necessary to situate this discussion within a social constructivist perspective of learning. Shulman and Carey (1984) describe social constructivism as a way of viewing the construction of meaning or psychological events through the reciprocal influence of individual and context. Social constructivism can be described as socialization, a process of acquisition of skills, knowledge and dispositions, that enables the individual to participate in his or her group or society. Vygotsky (1984) described how humans use cultural inventions, signs, and tools to mediate their interactions with one another and with their surroundings. A fundamental property of these instruments is that they are social in origin. First, they are used to communicate with others and to mediate contact with our social world; later, these instruments can come to mediate our interactions with self, as they can help us to think as we internalize their use. Both the means of transmission of culture and knowledge and the implicit sociocultural meaning given any event or activity shape the way we think and act. A human's actual relationship with reality is heavily mediated by social relationships, tools, and artifacts. Meanings are considered to be established interpersonally before they become intrapersonal. The socialization process consists of reciprocal interactions and joint construction of meaning by the individual and others in the social context. Language is central to this view, as we communicate and engage in dialogue with others (Bakhtin, 1986).

Social constructivism has been primarily a theory of cognitive development whose emphasis shifts from the

individual as meaning maker of the interaction to a view of collectively-constructed meaning. Gergen (1985) explained social constructivism:

> "…what is taken to be psychological process at the very outset becomes derivative of the social exchange. The explanatory locus of human action shifts from the interior region of the mind to the processes and structure of human interaction. The question of why is answered not with a psychological state or process, but with a consideration of person in relationship." (p.266)

It is important to situate our understandings of the students' reflection on their interactions with the middle schoolers within this perspective of meaning-making as this provides a way to examine more closely the context of the learnings that occurred.

Design thinking was embedded within this social constructivist perspective on learning as both the university students and middle school students grappled with this approach in the afterschool program and the course. Design thinking is an orientation toward learning that encompasses active problem solving and believing in one's ability to create impactful change. The focus of the process is for students to be able define the parameters of a problem, identify needs, deal with varying levels of ambiguity, actively solve problems, and make connections between their lives inside and outside of school. The key components of design process are that it is (1) human-centered, (2) action-oriented, and (3) mindful of process (Hasso Plattner Institute of Design, 2007). Figure 1 highlights the five key phases of the design thinking process: empathize, define, ideate, prototype and test.

Design thinking provides a robust scaffold for divergent problem solving, as it engenders a sense of creative confidence that is both resilient and highly optimistic. The need for this kind of approach is timely. Today's students will be expected to collectively tackle 21st century problems, yet only 16 percent of teachers reported they are assigning projects that help students develop problem-solving skills (Project Tomorrow, 2009). Research has indicated that many first-year college students need further development in critical thinking and problem solving (Lundell, Higbee, Hipp, & Copeland, 2004).

Figure 1. The Design Thinking Process.

Promise for design thinking has been shown in several projects (Carroll, M. et al., 2010); (Hmelo, Holton, & Kolodner, 2000). Work in mathematics (Goldman, Knudsen, & Latvala, 1998), science (Kolodner et al., 2003), and technology (Kafai & Resnick, 2002; Todd, 1999) suggest that design thinking skills are not merely extras, but can in fact aid students in core subject areas as well as building cognitive and social skills. It is an important and highly useful mode of inquiry that puts "doing" and "innovating" at the center of problem solving. It has the potential to engage students in ways that are inclusive of their diversity, makes school learning relevant to real, pressing local and global issues, which can enhance motivation to learn, and creates a "third space" (Gutiérrez, 2003) for students where they can develop agency, confidence, and identity as change agents as they respond as innovators to the interdisciplinary nature of design challenges. Early work in this domain has indicated the potential for design in K-12 to contribute to young people's metacognitive (Kolodner, Gray, & Fasse, 2000) and social learning (Cognition and Technology Group at Vanderbilt, 1999), as well as in specific subject areas (Goldman, Knudsen, & Latvala, 1998); (Middleton & Corbett, 1998). Vande Zande (2007) characterizes design thinking as a means of creative problem solving that relates thought and action directly and dynamically. Design has the potential to impact learning-to-learn skills such as working in groups, following a process, defining problems, and creating solutions (Barron, 2006). The methodologies of design thinking and rapid prototyping play important roles in developing transformative advances in learning and teaching (Cobb, DiSessa, Lehrer et al., 2003); (Design-Based Research Collective, 2003). Davis et al. (2007) propose that:

> "Design is a creative counterpart to the scientific method, and it presumes that there is more than one right solution to any problem and many paths to each alternative…for designers, doing is a way of knowing. They are as likely to analyze a problem through models, diagrams, walks through an environment, or sketches as they are through statistics or writing. Designers are fluent in several vehicles of thought (images, words, numbers) and methods of communication, storing and recombining experiences for future use." (p.2)

It is critical to focus on creating learning environments that teach the fundamental mindsets and processes of design thinking and are entwined with content learning (Carroll, M. et al., 2010). This is particularly relevant to STEM education and the Diamond Afterschool Program. The Center for Teaching and Learning (2010) report that in California, only 10% of elementary students regularly receive hands-on science lessons; they arrive at middle school unprepared for and uninterested in science. In addition, only one-third of elementary teachers said they feel prepared to teach science, and 85% said they have not

received any training during the last three years. According to the Carnegie Foundation Commission on Mathematics and Science (2009), the United States needs an educated young citizenry with the capacity to contribute to and gain from the country's future productivity, understand policy choices, and participate in building a sustainable future. The need for knowledge and skills from science, technology, engineering, and mathematics are crucial to virtually every endeavor of individual and community life. In a National Academy of Science (2007) comprehensive report on STEM education, it is recommended that there is a need to (1) increase America's talent pool by vastly improving K-12 mathematics and science education; (2) sustain and strengthen the nation's commitment to long-term basic research; (3) develop, recruit, and retain top students, scientists, and engineers from both the U.S. and abroad; and (4) ensure that the U.S. is the premier place in the world for innovation.

The Diamond Afterschool Program provided opportunities for students to learn about STEM careers through the interactions middle schools students had with their university mentors. The National Science Foundation describes how "…informal learning happens throughout people's lives in a highly personalized manner based on their particular needs, interests, and past experiences"(Dorsen, 2006, p.3). This type of multi-faceted learning is voluntary, self-directed, and often mediated within a social context (Dierking, Ellenbogen et al. 2004). Young people cannot choose a specific STEM career or field of study if they are not made aware of the diverse range of possibilities and the paths they need to take to achieve their goals. The Diamond Afterschool Program introduced middle school students to STEM careers in a multitude of ways. Tafoya, Nguyen, Skokan, and Moskal (2005) describe the critical importance of middle school as a time for either encouraging or discouraging students' participation and interest in mathematics and science. Middle school students exposed to pre-engineering experiences have more positive attitudes to science, mathematics, and engineering and have greater knowledge of engineering concepts than students taught only through traditional middle school mathematics and science curricula (Hirsch, Carpinelli, Kimmel, Rockland, & Bloom, 2007). The Diamond Afterschool Program with its focus on the intersection of design thinking, STEM careers, and mentorship provided a means to address these critical issues.

Methodology

Qualitative methodologies (Bogdan & Biklin, 1992) were employed in data collection and analysis. The findings presented in this paper are grounded in a four-month ethnographic study of a university/afterschool program in an urban setting in the east bay area of San Francisco. University participants and middle schoolers engaged in design thinking and STEM activities. The main data source for the research was retrospective journal reflections of university students that described their afterschool program experiences with middle school students and their classroom experiences. This data was collected during the university quarter and analyzed over the course of the subsequent nine months.

Sites

Whitfield University is recognized as one of the world's leading research and teaching institutions with an approximate five to one student-to-faculty ratio. Whitfield offers three undergraduate degrees—Bachelor of Arts (B.A.), Bachelor of Sciences (B.S.), and Bachelor of Arts and Sciences (B.A.S.)—each designed to achieve balance between depth of knowledge acquired through specialization and breadth of knowledge gained through exploration. Of the seven schools at Whitfield University, three award undergraduate degrees: Humanities and Sciences, Earth Sciences, and Engineering. Enrollment consists of 7000 undergraduates and 8000 graduate students.

Milagra Academy is a college preparatory secondary school dedicated to preparing all students for acceptance and success at the four-year college or university of their choice. Their mission is to equip their students with the academic skills, behaviors, habits, and qualities of character necessary to successfully complete college so that they have the opportunity to earn a family-sustaining income and make a positive impact on their community. The school was founded in 2006 in a community where 10% of the residents have a Bachelor's degree and the high school drop out rate is over 70%. There are approximately three hundred students in the school, and 97% of the students participate in the federal free/reduced lunch program. 90% of the students speak English as a second language and 97% of the students are first-generation college students. The ethnic background of the students is 86% Latino, 11% African American, 3% Asian/Pacific Islander, 1% White/Other.

The Diamond Afterschool Program ran for seven weeks, and 36 seventh- and eighth-grade students participated. Their participation was voluntary. They were divided into groups ranging from three to five students. The eighteen Whitfield University mentors were divided among the groups. Each weekly afterschool session was one-hour long. Milagra University was chosen because the researchers knew of its interest in design thinking and its interest in providing opportunities to partner with the local university.

Course Description

The university course met for ten weeks, twice a week. Students who took the course were enrolled in the following programs: Civil & Environmental Engineering Master's program (two students), Civil & Environmental Engineering doctoral program (four students), Mechanical

Engineering doctoral program (one student), Management Science & Engineering undergraduate program (one student), Education doctoral program (two students), Education Master's program (two students), Earth Systems Master's program (one student), Engineering undergraduate program (one student), Biology undeclared program (one student), and one undergraduate student had an undeclared major. The students taking the course met on Tuesdays in a university classroom and on Thursdays at Milagra Academy. The mentoring began in the third week of the course, and all students were required to be mentors.

In the first weeks of the course, Whitfield University students learned about design thinking, adolescent development, the STEM pipeline, water issues, curriculum development, and mentoring. There were required class readings, discussions, lectures, demonstrations, and hands-on activities each week designed to provide background information that would be helpful for the students prior to beginning their work with the middle schoolers. The afterschool program started the third week of the university course.

The university students were given wide parameters to make decisions about what activities would work best with middle schoolers, as this experience was designed to provide university students with freedom and responsibility as designers and mentors. The students created a wide range of activities based on STEM topics, water, and design thinking. The students created activities during class and shared them with their classmates and instructors to receive feedback before implementing them in the afterschool program. The groups also met outside of class time to prepare for working with the middle schoolers.

The students drew upon their knowledge of engineering and design thinking as they designed activities for the middle schoolers. Their activities focused on developing empathy for others, generating creative ideas, and building iterative prototypes. They wanted to introduce STEM careers, knowledge about STEM topics, and information on water.

In the "Water Without Faucets" activity, students compared their own experiences of water use with the experience of people in developing countries. The middle school students were divided into teams: one team used faucets to fill large buckets with water and the other teams had to use small buckets from a container to fill their buckets to replicate what it would be like to not have access to a faucet. The teams competed to see who filled their buckets more quickly. As a closing activity, the students reflected on the difficulties of living in a place where there is not easy access to water. In the "Gummi Bear Water Tower Challenge," students worked in teams to build a water tower with the following materials: playing cards, scissors, scotch tape, Gummi bears and marshmallows. A hair dryer was used to test each structure's stability. Students learned about physics as they built their towers. The "Water Taste Test" challenged students to discern the difference between bottled water and tap water and raised their awareness of issues surrounding plastic bottle use and recycling. In the "Sink It!" activity, students learned about buoyancy, surface area, and density. They worked in teams to create boats made of aluminum foil and added coins to see whose design could hold the most weight. The university students also included improvisation activities in their time with the students to act as icebreakers, provide bonding opportunities, and energize the students and have fun with them.

Data Collection

Whitfield University course participants were required to reflect on their experiences in the Diamond Afterschool Program and in the course itself in a journal. They were asked to respond the following prompts:

- Why did you take this course?
- What expectations do you have for your experiences with the middle school students?
- What was the most surprising thing that happened with the students?
- Were there any issues that came up? Please explain.
- Were there positives for you? If so, please describe.
- What ideas or insights did you get about mentoring, middle school students, or STEM?
- Please add anything else you would like.

Student journal reflections occurred once a week for ten weeks. The university researchers collected eighteen student journals.

Data Analysis

Following guidelines for inductive research (Strauss & Corbin, 1990), the journals were read and re-read several times. The goal was to gain a general or global sense of the nature of mentoring, STEM learning, and design thinking from the perspective of the mentors. The first readings were to try to understand what occurred in each afterschool session and how the mentors felt about their experiences and interactions with the middle school students. The unit of analysis was a journal response to one or more prompts. Phenomena were clustered into larger conceptual categories, which were then developed into assertions. Each assertion is highlighted by the creation of thematic vignettes, which describe the nature of the mentors' interactions and learning from their reflections on their work with the middle schoolers. The vignettes contain data and commentary and analysis that highlight the key themes.

Findings

This section of the paper highlights the findings from the data analysis of the student journals. Three key themes emerged:

1. The Dynamics of the Mentoring Relationship;
2. The Nature of Designing of Instructional Activities; and
3. The Role of Design Thinking.

Theme 1: The Dynamics of the Mentoring Relationship

As the mentors interacted with middle schoolers, different aspects of the relationship became evident. The nature of the mentoring relationship was characterized in the following ways:

- inspiration
- defining one's role
- balancing authority
- making connections
- building rapport
- building a team culture

ASSERTION: Mentors felt a responsibility to share their own inspiring STEM experiences with middle school students.

Pay It Forward

The Whitfield University students shared stories of how mentoring shaped their lives. They were inspired, challenged, and encouraged by those who worked in STEM fields, and felt it was important to "pay it forward" as they worked with the young middle school students.

> *"As an engineer, I know firsthand that a few key mentors can make all the difference in grabbing the attention of young scholars and attracting them to STEM fields. As a beneficiary of some great mentorship, I consider it my duty and also my passion to help others to explore their interests and believe in their abilities in STEM fields."*

> *"I feel that it is my responsibility, especially as a female engineer, to teach a new generation of students and instill in them the same passion for learning I have."*

> *"I am excited to see the enthusiasm by both the young girls and boys for STEM-related fields… I really hope that we are helping play a role in the development of the next generation of scientists, mathematicians, and engineers! I had really meaningful and inspiring mentorships in my early STEM career, and hope that we have already provided—and will continue to provide—a similar experience for the middle school students at Milagra Academy."*

ASSERTION: Mentors see themselves as role models for the students they are mentoring in diverse ways.

I Was You

For some mentors, being a role model was about challenging preconceived notions about what an engineer is.

> *"If a Whitfield University student could play all the sports… and still be a "nerdy" engineer, maybe they could too."*

> *"As a former chemical engineer I understand the preconceptions that surround the engineering field and attracting talented students to the field…I am specifically interested in helping more women and underrepresented minorities understand more about engineering and possibly pursue engineering careers."*

> *"It may be more beneficial for the students to know they have a cool friend who is an engineer rather than coast through some activities."*

It was also about realizing how much of an impact the mentors' actions had on the middle school students.

> *"We started with icebreakers and name games. At the beginning students did not even want to say their name. However the energy of all the Whitfield students was infectious. The students really mimicked us. I continued to realize our power as role models for how the students should conduct themselves."*

> *"I know now that the ultimate goal is to get these kids interested in STEM fields because we are real examples that exist evidencing that they are fun and engaging fields. We're there to show them that we were them! And that they can become like us too! They don't necessarily follow our stories like a script, but more as an inspiration to take a small curiosity and interest in science as a means to go into STEM fields."*

> *"I asked one of the students to tell me her favorite part of the day. She specifically mentioned my STEM bio as being her favorite and said she thought it was cool how 'chemistry is all around us.' It was positive to see that my story made an impression on her in such a small amount of time and I am excited that she now sees chemistry in a new light."*

> "*In this course, I was able to act as a STEM mentor and by the end of the course, several students in my group said things like "You see what I am trying to do is get my grades up so I can work in a lab" or "I am going to work hard so I can come to Whitfield." On our final tour, one student was making connections between large Kinex structures in a Whitfield lab and his own Kinex truck at home. It was experiences like these helped these students to start envisioning themselves as scientists while also giving them information about the path to accomplishing that goal."*

ASSERTION: Mentors negotiated their developing relationships with students by attempting to define their roles.

Defining Me, Defining You

An important part of mentorship was the definition of roles. The mentors were given a lot of leeway in how they would engage with the students, which was both a challenge and an opportunity.

"For me, the major insight about mentoring was how different this experience will be from classroom teaching. As a classroom teacher my role was historically very clear to my students and to myself. As a mentor, the role is more ambiguous than I originally anticipated."

"…one of my insights…was that perhaps being a mentor does not necessarily mean doing the activity with the student or even helping the student do the activity. Sometimes it may just mean talking to him or her."

For many of the mentors finding a balance was critical.

"I want to be wary of mentoring "too much"… In other words, I want to make sure I'm striking a good balance…But in a more interpersonal sense, there's also a difference between mentoring and teaching. A lecturer talks at an audience, a teacher engages with an audience but is the predominant "talker" in the conversation, and a mentor engages with a mentee but is equally a talker and listener."

"And after our hour on Thursday is when I realized that I struggle with finding the balance of telling the kids what I think and allowing them to think on their own. I'm definitely extremely enthusiastic when talking to Milagra kids, but I'm wondering if that translates to babying them. Because when some of my colleagues talk to them like they're actual adults, the kids choose to disengage. I definitely think you can be enthusiastic and inspire energy without intruding on their sense of adulthood."

Some mentors described the differences between formal teaching, tutoring, and mentoring as they struggled to define their role. While they struggled, they still remained quite optimistic regarding their impact.

"However, I do worry about the implications that poor math preparation might have on their future careers; unfortunately STEM is a field in which passion will get you far but at least some ability is needed. Even still, I must resign myself to the fact that when I am at Milagra I am a mentor, not a tutor."

"…if you are trying to mentor kids about STEM fields, you should not structure your activities like a classroom because then you appear as a teacher not a mentor."

"The concepts are important, but I don't think formal teaching is really possible in the time that we are allotted…I think it is more important for us to be a mentor than a teacher. If we engage the students through fun and competition and make it clear that we are representing the STEM fields, it will ultimately be productive. This is a process. We can't fix the educational inefficiencies in an hour, but we can positively impact these students."

"I learned that mentoring is very different than teaching and tutoring… Mentors must build meaningful relationships with students from the ground up. Some of the aspects involved in this are similar to teaching, such as sharing your personal story and information about who you are but other aspects are different such as shaping activities primarily based on student interest rather than goals associated with content mastery. There is also a different outcome of mentoring such that in teaching, you hope that students will learn content and also be influenced regarding their futures. In mentoring, the influence is the priority and the content learning is secondary. This was a huge flip for me but a really important thing to understand."

ASSERTION: Mentors negotiated the boundaries of authority as they built relationships and worked with middle school students.

Authority: How Much, How Little?

The question of authority resonated with the mentors as they negotiated the developing mentoring relationship. How much authority did the mentors want? How much did they have? How much did they need?

"In a mentorship relationship with students, there is far less implicit authority in the roles indicating that the mentor must connect with students on a level that supersedes normal school roles."

"I realize that I also have trouble telling a student that he/she is doing something wrong, or in a way that doesn't contribute to the learning experience."

"…I am negotiating the new territory of mentor through my experiences as teacher. As teacher, I commanded attention of my students, as mentor- the students have no built in incentive for listening to me."

Some mentors questioned if they wanted to appear as an authority figure to the middle schoolers.

"I was the last STEM bio presentation of the day and the students were not that attentive. I think this was partially because it was the end of the day and the students wanted to leave and partially due to the subject I picked. Since people weren't listening, I rushed to finish which didn't help the students understand my bio. In a different situation, I would have commanded more respect from the students but it is difficult to do without appearing as an authority figure."

"My biggest lesson learned from working with the students was to shy away from being an authoritarian. The students know how to act, and I think they enjoy freedom."

"I also felt very strange being an authority figure and giving instructions; I never saw myself as someone who

could do that and be taken seriously. As a result, for the first couple of weeks, I hung back and did not talk to or with the students as much – this was a big mistake! Eventually I learned that if I wanted to engage with the students, I would have to be the adult I was and initiate conversation myself. I asked them questions about their school day, families, and hobbies, and I could see them begin to warm up to me."

The mentors tried different strategies in the activities they did with the students.

"I loved going to Milagra and working with the students. It was really nice to see them break out of the traditional relationships and interact with us as respected peers…I think that during our time at Milagra, I was able to get better at finding a balance between treating the children like adults but also not making them feel inadequate."

"In prior weeks, I had struggled with how much guidance to give the students, wanting to give them guidance without telling them exactly what to do. This week, it was very much give-and-take between Sonia, Billie and me. We treated Sonia as an equal, encouraging and building on her ideas but also suggesting ideas of our own for her consideration. We were also much more hands-on with the build than last week. I got the sense that Sonia… liked this treatment, the feeling like they were one of us. They definitely rose to our level as well, not being afraid to speak up and suggest their own improvements on our ideas too."

ASSERTION: Mentors found that building relationships with the students was both challenging and rewarding.

Commonalities, Connecting, and Caring

Connecting with students was an essential part of the mentoring relationship. Sometimes it was about finding common ground with the middle school students. The mentors expressed some anxiety before the first session.

"I wondered if I would connect with students in meaningful ways, if our short time together could really make a difference, and even if they would make fun of me."

"I expected that students would not warm up to us due to our first interactions. I thought that they would think that they were too old to engage with Whitfield students after school."

They reflected on their experiences in engaging the middle schoolers.

"The students are very receptive as long as we find the right place to meet them."

"I think the session really proved to me that "getting on their level" is going to be key to mentoring middle school students. These kids want to be able to relate to us- what we like, what we don't like, what we think is cool, etc."

"…I loved my first visit to Milagra and took away some important mentoring lessons. These included asking questions to find common ground with a student…By listening to his answers and asking follow-up questions, I found that Javier and I share a love of building things with our hands…These moments, when I felt like I connected with Javier, were the best moments of the hour."

"…it was interesting to see how the students reacted to the games we played outside. They were still clearly a little shy and intimidated, which makes the presentations and getting to know you process all the more important."

"In the beginning, our team was really focused on getting through the activities and thus didn't take the time to get to know the students personally. Later, our team built in more down time so we had the opportunity to have more informal conversations with the students."

"I was very focused on changing student behavior and appreciation of the environment through science lessons and activities, whereas now I think that just sharing with them my beliefs and interests and really getting to know them as people may be just as powerful a tool for inspiring them to change."

Building Rapport One Day at a Time

Building rapport was also a challenge, and different mentors had different strategies. For some it was about the importance of individual relationships.

"They are much more inclined to listen to what we have to say, if we show that we're interested in what they have to say."

"All of this stress melted away when I heard Victor greet me as I hustled into Room 121. I was pleasantly surprised that he remembered me and that he was so outgoing in finding and greeting me. In our short two-minute conversation, we continued to build rapport that I look forward to nurturing through the rest of our visits."

"Working with students this past week reminded me of the power of individual attention. In the beginning of our mini-activity, David sat slightly away from the table where everyone else put their paper and stared over the railing. His physical location isolated him from the group—and this was the result of a larger group, not entirely his own choice to sit slightly away from others. After noticing his disengaged stare, I crouched by his side and asked him questions after he marked his

answers. He answered each question more confidently. When I moved away, he blurted out an answer with a hint of excitement in his voice."

"I really enjoyed that I got one-on-one time to talk with some of the kids and to get to learn more about their lives outside of STEM subjects."

"This week I think the best part was seeing the kids be able to relate to what we were telling them about ourselves, for example, them saying that they loved Drake or that they played sports just like us. It was nice to know that in some way our stories were reaching them, whether it was because they recognized a place in one of our pictures or because they liked the song that someone played for their presentation. It's awesome and refreshing to see their faces light up when they find out that we play basketball and they do too!"

For some mentors connecting wasn't easy, even as the weeks passed. Yet the more they learned about the students the more they adapted.

"The only issue that came up was that we had a new girl added to our group this week who would not engage with the activity at all. She wouldn't even sit down with us while we were working on our filters, despite the multiple times we invited her to do so (even one of her classmates invited her to sit down and she wouldn't!). In addition, I tried talking to her on the side to tell her that we would love her help and input on our filter, but she would not budge. We also had a mini-discussion before jumping into the filters, and when she wasn't responding to questions I tried making the answers non-verbal (thumbs up, thumbs down), but this didn't work either. The only thing she would tell us was her name. It was really frustrating!… I tried everything I could think of though to get her engaged and she simply would not respond."

"Even in the third week of visiting the school, I can sense some students being affirmed and some students not. Some students have been excited and vocal since the first day—and I sense their excitement increasing. I find it easy to latch on to their excitement. However, what about the students who have disengaged? I want to make conscious efforts to reach out to them, believing that even one conversation can draw them into an activity."

"I learned from these sessions how to be more in-tune with how middle school students interact socially. I was surprised at how difficult it was to get the students to act out charades or jump around and be silly in our initial sessions. Also, it definitely took time for the students to trust us, perhaps all the way to the last session. I learned to be aware and respect what our students were going through in terms of personal development. Their strong need to fit in and not stand out, and at the same time feel unique and special. I think mentoring requires a lot of effort to understand and respect the students, and that it takes time to make the connection."

"…I know that I am really reserved. It was no surprise to me then when my more outgoing classmates seemed to get better responses from the students. So, just as I tried to make more of an effort to engage them in conversation, I started faking extraversion. I gave the motion name game my best shot and made extra fuss over their designs, because while the actions might be feigned, the intentions behind them are not and I really wanted the students to see that. I am hoping that as I work on this more, engaging others will come more naturally to me."

ASSERTION: Mentors became aware of the critical impact of building a team culture in working with middle school students.

Team Culture Building

Since many of the activities were team-based, building a team culture was an important aspect of the developing mentorship relationship.

"While middle school students have a bit of wacky spirit in them, it is ultimately the role models who set and maintain team culture. If we as leaders continue to model team spirit, the group will feel more comfortable in doing the same. We need to maintain this attitude even when we feel the students do not respond in the same way."

"I am reminded of the impact of the energy of one student. We had a new student this past week, and she engaged the other students. With the energy of one student—or, with the disengagement of one student—it can turn the tide of group dynamics."

"We also incorporated sports into our debriefing activity because we threw around a tennis ball in our "say anything" activity. And the random conversation within our circle was a combination of insightful comments, witty responses, and interesting tidbits about their lives."

"When we began I didn't think that we would have enough time to bond with the students. However the students really looked up to us, and developing relationships was very natural because of the activities. Since we were not really teachers, we experienced the process very similarly to each other. We built together and brainstormed together which was really effective. Ultimately the mentoring was an organic experience of mutual growth with the students."

Theme 2: The Design of Instructional Activities

The mentors used the insights they gained about building relationships with their students to inform the instructional

design of the afterschool program activities. This was highlighted in the following ways:

- knowing the students personally
- being flexible and responsive

ASSERTION: Designing and implementing STEM activities for middle school students is challenging, therefore knowing the students as people was essential.

The Importance of Knowing

The mentors thought deeply about their growing relationships with their students, and they applied the same care to making sure their instruction was effective. They focused on goals, questions, and assumptions. The mentors used what they learned about connecting with the middle school students as they designed activities. They found that there was a strong relationship between knowing their students and instruction.

"I learned that working with students is all about connecting with them at the level they're at – whether that's their interests or their energy level for that day or whatever else might be influencing their ability to learn. If you can't listen and try to make the activities or mentorship about the relevance of this education to their lives, then it becomes difficult to have the students empower themselves. The other thing I learned is really just to trust the intelligence and ability of these students to figure out the task on their own."

"I am also seeing the value in building in 'dead' time into the hour because it allows us to discuss more about our backgrounds and get to know more about the students. This week I learned that the students live in an area called 'Westfield Park' and walk to school."

"In terms of mentoring, when talking to the students some of them said they would rather be texting their friends or on Facebook than at our afterschool program. This was an important insight because it helped me understand what types of activities this age group enjoys. I am now wondering how to better incorporate social media into a STEM activity."

"After prototyping the shake-out activity with the class, I expected it to be well-received and fun! This was not the case at all! The students showed to be highly self-conscious and reluctant to participate so by the end of the shake out, only the mentors were shaking-out and shouting counts. I think this had a lot to do with the boys that were playing with a ball in the field nearby, which understandably made the girls uncomfortable participating in an activity made to make everyone look silly. Furthermore, the girls really did not like the idea of shouting the counts out loudly because it drew apparently unwanted attention to our group. I was very surprised with how out of touch I was with the middle schooler students' mindsets and what I thought would be "fun" for them! I learned that I need to be very sensitive to the potential self-consciousness of the students when developing activities."

"Our group decided to incorporate improvisation activities in our hour. I was unsure about how much it would work. I've done it with young kids before and it has been a lot of fun. However, improv is the type of activity that you need to get over your inhibitions before participating fully. There were one or two students in the group who acted as though they were too cool for the activities, which ruined it for everyone else."

The mentors showed a great deal of empathy for the middle schoolers. This became apparent in how they interacted with students and how they designed and modified their instructional activities.

"One new insight I got about mentoring the students this week is that when they are tired and have low attention spans already as a result of being in school all day, any activity we do needs to be primarily fun. In addition, I think I am biased as to what I think of as fun. I'm a scientist and so I think things like learning about energy in food is fun, but if you aren't already on board the STEM ship, that might not sound fun at all!"

"Also, I think that in an attempt to get them to participate during the presentations, we started to treat them as though they were much younger than they actually are. I know this would have upset me when I was their age and I hope we can avoid that next time."

"I learned to be particularly sensitive to middle school students' need to "maintain [their] reputation"! More generally, I became much more aware of the way they handle the social pressures of middle school and tried to be hyper-cognizant of this while developing activities."

"I learned that it was really important to make the topic cool to the students. The students have access to so much entertainment, that even teaching kids, the format is really important to catch their attention. As educators, we're also competing with all other forms of media to get the kid's attention, so in some ways this makes our work more challenging, but perhaps it also teaches us to present material better. Perhaps one way to do this is to choose completely different media. For example, instead of using PowerPoints and videos, using more hands-on activities, so that it changes the mentality of the learning process. Getting the kids to move, or giving them a puzzle to solve is really important in building their investment in the learning process."

"I also found that the nature of the STEM bio was quite an intellectual topic. My reasons for becoming interested in biomechanics were academic in nature and I realized during my presentation that this is not very relatable to

many middle schoolers. I am interested in how effective it might be to ask the students to think of and draw upon synonymous experiences, instead of trying so hard to get them to understand and relate to my experiences."

"In my first reflection, I hoped that working with students outside of the classroom would bring more freedom in their learning experience. I do not feel that I fully took advantage of the informal learning environment. First, I do not think that I fully understood the informal learning environment. I initially thought that I would continue to teach students learning objectives. Instead, perhaps experiences characterize the value of spaces outside of the classroom. In other words, perhaps my role as a mentor may be to give students holistic experiences that spark their interest in an idea—that make them curious about an idea. This interest piece can be lost when thinking about objective-driven activities because, in this case, I often seek to control what students learn rather than let them interpret the activity according to their interests. It is valuable for activities in informal learning spaces to have objectives, but I may have brought too strong of a lens of classroom objectives to the learning space."

"As you would expect these kids are way more concerned with Facebook and their social life than learning about STEM. But in that same light the students the stated that after a day school they are tired. Their school seems to be very strict and structured and by four o'clock they are looking to get away from that. I think that in the future we have to figure out how to deliver STEM information in a very unstructured way. Potentially we should just hang out with the students for an hour. It may be more beneficial for the students to know they have a cool friend who is an engineer rather than coast through some activities."

ASSERTION: Mentors experienced the tension between the ability to respond to what occurred as the activities unfolded "in the moment" and their pre-activity planning. Responsiveness, Flexibility and A Little Bit of Silly Goes a Long Way

Being able to adapt was an important learning for the mentors. They learned how to respond to what was happening, change gears, and let the students guide their next steps.

"I think it is more important not to go into a presentation to middle schoolers with too much of a plan. That is to say, be prepared to stop and have questions that are not necessarily in line with what you intend to teach. You must be flexible when teaching/mentoring students. This allows you to draw connections to the material even though some questions may be off topic."

"I learned that some days will be better than others in terms of student focus, but that mentors have to keep their energy and focus up to lead by example."

"You have to be very flexible to make sure each student has a good experience. We worked one-on-one prototyping. The student that I worked with wasn't into the prototyping and building something so the best I could do was to get him to draw a picture. He was not into the water conservation topic at first, but he said he enjoys drinking water so we talked about how to make the water fountain at school better. At the end of the prototyping session we then moved onto ways the water fountain could be used to conserve water. He actually had some good ideas of recycling and treating the waste water from the fountain."

"I think the biggest insight for me this week was that silliness is a huge part of interactions with middle school students - and I think it's part of what makes the experience rewarding. This week Jaden drank from the "polluted" water with the oil and ketchup and said it tasted delicious. We all laughed and had a great time from his comments and from his silly actions."

"…as we were building our tower, Billy and I started laughing a bit because the tower was really unstable and kept falling down. As soon as we started laughing, Jack started laughing. Pretty soon we were all laughing hysterically. It was another special moment – one that I think I will keep in the back of my mind as we continue on with this course to remind me that these are the kinds of moments we want with the students. I think that the little connections, like laughing together, that we make with the students are just as important in getting them motivated about STEM as are the actual activities that we do."

"I learned to be responsive to student feedback, adapting lesson plans in situ, as they were occurring, to best address the students' needs, energy levels, and interests at the time of the activity. This exercise in needfinding was vital to developing effective and fun group activities and lesson plans."

"Being flexible and not getting frustrated when things don't go as planned is the separation between having an impactful day and wasting time."

"This week I learned that one part of mentoring and STEM is letting the students take control of the show and just following their lead. One of our students was having a great time with the activity, to the point of going a little overboard making "dirty water" and using materials up. My initial reaction would have been to reel him in a little bit to keep him a bit more on task, but instead our group ended up letting him push the limits. It might have ended up a bigger mess that it was supposed to be, but I'm really glad we let him go ahead and do it. I think that the freedom really allowed him to be creative and do STEM the way he wanted to do STEM. Sometimes STEM activities can be a little restraining because they usually have an end result that is supposed to be "cool" or "exciting" or something, and then if the students

don't think its cool it is a little disappointing. When we let our student just kind of do what he wanted with the materials we gave him, I think he found it even more fun and cool than he would have if we had made him follow the "right" instructions. Giving him that kind of freedom might have gotten him even more engaged in STEM than following the instructions could ever have."

The Role of Prototyping and Planning

The mentors used their university class time to plan the instructional activities. It seemed there was tension between planning and responding in the moment.

"Insofar as whether the Milagra students took from our activity what we hoped they would, I think the results were mixed. One of the major lessons was that, as we collect more information about a phenomenon, we become better able to make predictions about it. Students in both groups demonstrated this principle in two ways; first, they combined their performance with their knowledge about how the body works to make more accurate estimations before every successive run, and second, they also adjusted their estimates based on information they had gotten about their friends' guesses and performance. They also demonstrated understanding that running backwards and sideways takes longer than running forward because physiologically it is "more difficult", i.e., you must go slower and take shorter steps to transverse the same distance. While this was a positive, looking back, I feel that we may have missed an opportunity to formally introduce the Milagra students to velocity. I also wonder whether, if we had begun the activity with a mini-lecture on velocity (or estimation for that matter), they would have internalized the concept better. However this is difficult to know since it is not clear how well or not well the students understood it as we presented it today without a mini-lecture."

"I'm interested in how to foster a conversational atmosphere where everyone wants to participate in a lively conversation. I found that even though I had incorporated many questions in my presentation, most of the kids did not feel like answering…I think I would benefit from prototyping my questions with others and seeing how much they can and want to talk on the subject."

"This was the week for which I felt best prepared going to Milagra. After brainstorming activities and fine-tuning them, I felt like my group had a cohesive vision for this week's visit. We planned to focus on brainstorming through playing an introductory game that involved memory and creativity, designing a team name and team cheer, and finally tying everything back into water by brainstorming ways that we use water in our everyday lives. Our group met for 45 minutes on Wednesday, which helped us cement, develop, and prune our ideas. By the end of this process, I felt confident in our ideas and their implementation, especially since the total hour of activities was really a combination of everyone's ideas and something that we all believed in… Our preparation certainly paid off in my comfort level during the activity and what the students seemed to take away from it."

ASSERTION: Mentors saw the value of fun as an essential part of learning.

Fun and Learning

The mentors reflected on the intersection of an engaging activity and learning. They explored the role fun played in learning.

"I think the biggest insight for me this week was, again, that hands-on activities (whenever possible) best engage students' multiple intelligences and best teach a subject. Today really reinforced that message to me."

"And, finally, I learned that designing fun activities is key! The students readily absorbed STEM concepts when these were presented in a hands-on, energy-high, and engaging manner, as opposed to structured lectures or presentations."

"After all the trash was made, we one-by-one placed the trash into the water. Then we moved to liquid pollutants and they loved that even more. This is when I realized a little more of the obvious. Kids LOVE getting messy. They absolutely love doing thing with their hands but they love getting messy. I'm going to keep trying to incorporate the "messy science" projects into our water challenges."

"I learned that in this type of situation, it's important to emphasize having fun. Learning is important, but it doesn't have to be in a conventional form. Looking back, I feel like all of my greatest learning moments weren't the result of a structured plan, so it's important to connect with the students first and then try to help them learn something."

"…I think that it might be a better approach to design activities with fun in mind and then subtly slip in that this might be STEM-related in some way, instead of trying to teach them about STEM overtly. We might not even need to mention that any of these activities are related to STEM in some way. I'm not sure that is totally clear, but basically I think that my group this week might have thought a little too much about the activity being educational and about STEM, when it might have been more effective to just do something to get to know them better. That way they could have gotten to know us a little better too, or could have gotten closer to building a real relationship with someone who is a STEM person."

"This past week went SO well. I was so happy when we were leaving the school because we were really able

to connect with the students and had fun. I think we overcame a lot of the initial barriers with connecting with the students and can now focus on improving their learning experience. My group was teaching some of the students that had caused the most trouble in the past. I can't even begin to explain how differently the students were behaving. I think the key was to keep them constantly engaged by doing things. By the time they get to us, they've had a full day of school and just want to have fun. If we provide that opportunity, we're much more likely to get them engaged. They don't want to listen to a lecture. We had a lot of success with explaining concepts after we had them do something interactive for a long time…I want to make them feel as if the things they're learning could be used to solve real problems."

Competition was an important part of the fun—it sparked engagement and excitement. The middle schoolers thrived on it.

"This session revealed to me that when it comes to middle schoolers, competition seems to be the way to go. The design challenge where we split our group into two teams and had them compete for the tallest tower really was the first time I experienced these students being excited about what they were doing in our program. Additionally, in our whip at the end of our session, almost all of them said that they would really like more races or chances to compete against each other. They all seem to have a competitive edge that makes them really want to beat their classmates in whatever it is they are doing."

"Staging the activity as a competition, especially in teams of girls versus boys, also seemed to work well."

Theme 3: The Role of Design Thinking

The mentors and the middle school students learned to become design thinkers together. The following concepts were critical:

- the development of a prototyping mindset
- the development of creative confidence

ASSERTION: The design thinking process provides opportunities that foster the growth and development of a mentoring relationship.

A Prototyping Mindset

Design thinking is a process that is supported by essential mindsets: developing empathy, deferring judgment, and learning from failure. The Whitfield University mentors were learning about design thinking themselves throughout the course, so their learning was happening at the same time as they were developing activities for the middle school students. Dweck (as cited in Johnson, 2007) describes the notion of a growth mindset. She states that students are often praised for being smart rather than for their efforts and willingness to take chances: "When we praise children for their intelligence, we tell them that this is the name of the game: Look smart, don't risk making mistakes" (p.2). This promotes a fixed mindset, which is where one believes that intelligence is a fixed trait. The design thinking process, in contrast, complements a growth mindset. It is characterized by a willingness to take risks, to learn from failure and to have a strong sense of resiliency. The adoption of a prototyping mindset was an essential part of both the mentors' and the middle schoolers' journeys.

The mentors recalled their struggles with ambiguity and uncertainty.

"Reflecting on my own growth throughout the quarter, I am becoming more cognizant of my discomfort with uncertainty. This discomfort finds roots in a desire for something to be perfect. Two consequences arise: I spend much of my time planning without getting feedback from my "users" or my students, or I feel stifled because planning something perfect is… impossible, actually. A prototyping mindset has directly addressed this discomfort, and I want to internalize this mindset more and see what it looks like in teaching."

"I feel pushed to take a prototyping mindset—the thought I do not need to be perfect but need to try something and improve from there."

They applied a prototyping mindset to what happened when working with the middle schoolers too. For some mentors, this affected how they designed activities.

"Though both students and adults respond to failure with varying degrees of fear, I hope that I will be able to develop some activities that will help Milagra students let go of some of the fear associated with failure. Failing forward is one of my favorite design thinking mindsets and I think it is very important for students to be exposed to."

"I also learned that I tend to struggle when I am faced with almost complete freedom, as we were often faced with in this course. There were obviously restraints on the location and other logistics that had to do with the students, but besides those logistical constraints it was left extremely open as to what we chose to do with the students. Initially I felt pretty overwhelmed by that freedom, I think because I really didn't know where to start without more guidelines. By the end of the course though, I felt I did a much better job of embracing that freedom and letting it allow me to be creative instead of restrained. I think that I am certainly still challenged by such freedom but I am learning to use it in a better way than before I took this course!"

The impact of a prototyping mindset became evident in how some mentors interacted with and responded to the middle schoolers.

"I think I managed to strike a balance between guiding and challenging students in their thought process. Being forced to lead students even when I felt uncomfortable or unsure was a pivotal part of this process for me."

"I think one thing I learned this week about mentoring is that as much as I feel anxious about "messing up" in front of the students, it can actually be a good thing to show them that we are not perfect. For example, as I mentioned previously our design challenge didn't work out quite the way we wanted it to. The students figured this out, but instead of it ruining the session, they laughed with us as we tried to figure out how to make it more difficult and then rolled with it. I think it helps to bring us to an equal level of expertise, which is really important if we are trying to connect emotionally with these kids."

"I specifically enjoyed observing how the design thinking process helps students to negotiate their strengths, weaknesses and places of uncertainty."

"Bringing plenty of materials was also good planning on our part. Inevitably, some of the students' boats using the plastic wrap did not work, so wrap got ripped, paper cups soaked through, etc. Being able to replace the materials, and being willing to provide more than just the materials specified in the instructions, seemed to contribute to the success of the activity. It helped drive home to the students the point of prototyping and the legitimacy of failure. At one point, Jeanne was not sure if taping the ends of her straws would help the boat stay afloat better or not, but I felt really proud of her when she said, "It's okay, we can test it out and see what happens.""

"The most surprising thing that happened with the students this week wasn't actually during our STEM sharing activity, it was during the imaginary ball-catching sound activity that we did as a break in between the two sets. The students as a whole had trouble catching onto the game, but one student in particular had a lot of trouble with it. He got very frustrated and opted to sit out and watch rather than play, which was of course sad for the rest of us! I'm not sure why this surprised me so much, but maybe it was because it was not intended to be a test of any kind (it was just for fun!) and he got really upset about it. It was a good wake up call to the fact that although these students are starting to become more independent and adult-like in some ways, they are really still just kids inside and perhaps need reminders of when things are just for fun and when it is ok to make mistakes."

"I also learned that embracing that inevitability, instead of freaking out about it or getting upset about it, usually makes everything work itself out. For example, when we were working with the students on the boat-building activity and it turned out to be much easier than we expected, we all looked at each other and said "oh well," thought on our feet abut how to change it and then tried the change out. The activity worked out fantastically! The students knew that we had misjudged the challenge, but I think that seeing us react to our mistake in a positive way helped them realize that we were human and helped us to make huge steps as mentors. Finally in light of all this, I learned to not be afraid of making mistakes. It's not only part of the design process, but it can actually bring you closer to your students."

Others reflected on how they might embrace a prototyping mindset in their own classrooms.

"As a person who likes to plan, I felt stretched by the prototyping experience and challenged my notion that I previously practiced a prototyping mindset. Over the past couple of years, I thought I developed a prototyping mindset. In teaching, for example, I faced so many decisions: How will my students enter the classroom? How will I design group work? How will I arrange the desks? Since each question came with infinite possibilities, I told myself that I wanted to have the freedom to choose one and the freedom to learn from it if it failed. Given the high stakes of the classroom environment, this mindset remained a thought rather becoming an action. This epiphany now becomes apparent, as it contrasts with my experience in the course, where I had a safe space to practice a prototyping mindset. At first, I thought that I would spend a lot of time planning, but the time constraints did not allow for a lot of planning. My group needed to make a decision and go with it. When something did not go as planned, we immediately went back to the drawing board—literally. We constantly reflected as a class, stating "I liked" and asking "what if?" The design environment facilitated learning from failure, and I want to more consciously create this environment in my classroom."

Shoot for the Moon! The Power of Creative Confidence

Creative confidence is a cornerstone of design thinking. Kelley (2010) describes how "design thinking is basically a methodology that allows people to have confidence in their creative ability." Bandura (1997) describes that confidence as 'self-efficacy'—the sense that you can change the world and that you can attain what you set out to do. The ability to defer judgment of ideas, generate enormous quantities of ideas, and build on others' ideas is critical as one develops as a design thinker. This creativity was an important element of the mentors' work with their students.

The mentors described the students' creativity.

"…the kids were engaged with their conversations and with us. They were ready to commit to the activity and learn from it. And that energy just fed our own energy, and suddenly the whole room was full of it. It was amazing! The fact (that) they are kids added to the success and originality of our ideas too! Their young minds saw any idea as a possible on, which was refreshing."

"The kids had such a strong ability to really believe in the possibility of something or in other words to imagine something. And being around that imagination allowed us, as adults, to do the same!"

"I was most impressed and surprised with their creativity when designing the rooms! My impression is that kids this age sometimes get bogged down by being cool, but the design process was so cool for them that they didn't need to feel constrained and really let loose as they prototyped!"

"They were able to generate many, different ideas, building off each other and stretching the prompts with their creativity. There was a positive, high energy in the exercises and the mentors were careful to maintain this. I was happy with how we summarized all the brainstorming rules into the concise phrase, "[the only rule is you have] to think of as many, wild ideas as possible", which I think the students really embraced."

"I feel the design thinking process encourages ideas to shoot for the moon."

The mentors realized that the design thinking process had rigor and was rich in opportunity for building 21st century thinking skills.

"Design thinking is hard. It goes against how we were educated to problem solve in the school system. I want them to feel its difficulty."

"I will implement the design thinking process in my teaching and have my students use the design thinking process. First, the design thinking process has strong implications for curriculum design: it requires that I know my learners and constantly shape the curriculum to fit their needs. While it may seem obvious that the curriculum needs to address students' needs, the design process entails empathizing with students' stories and constantly trying new ideas. I have done these to an extent in my teaching, but the design thinking process gives me a mindset and protocol to approaching them. One of my major goals with students is to increase their sense of agency. I define agency as both a desire to want to affect change (I want) and a belief in ability to affect change (I can). The design thinking process influences both facets of agency."

In sum, the three key themes that emerged from the data were: The Dynamics of the Mentoring Relationship, The Nature of Designing Instructional Activities, and The Role of Design Thinking.

Limitations of Study

This study was conducted in an urban underserved middle school and a university. Further data is needed to provide a more nuanced understanding of how students engage in design thinking, and to create a more holistic picture of evidence of the underlying mindsets that support this approach to learning. A larger sample would provide more comprehensive data. In addition further research on how students are inspired to pursue STEM-based careers, multiple pathways of mentorship and how design thinking, mentorship, and STEM learning support each other is needed. Data was collected from mentors, but data was not collected from the middle school students.

Implications for Research

This study consisted of analysis of student reported retrospective data. Questions for further research arose, which included the following:

- How can mentors engage most effectively with students? What strategies enhance these interactions?
- What kinds of content and learning materials best enhance student engagement?
- How can we introduce design thinking as a 21st century learning approach most effectively? Conversely, what are the limitations of design thinking?
- How can we create design thinking best practices to support STEM learning for students?
- How can we most effectively expose students to information about the wide range of STEM careers?
- How can mentors inspire students to learn more about STEM careers?

Much research remains to be done as we learn more about STEM learning, middle school students, mentorship, and design thinking in 21st century learning communities.

Implications for Practice

The goal of this study was to extend the knowledge base that contributes to an improved understanding of the role of design thinking in K-12 education, explore issues surrounding the STEM pipeline, and understand the nature of a developing mentoring relationship. The biggest learning was how design thinking provided a frame within which students learned how to be mentors, how to create user-centered learning experiences, and how to share their experiences as developing STEM professionals with middle school students. By employing an experiential approach in the use of design thinking the mentors learned more than simply a process—they truly experienced the

development of the mindsets that characterize design thinkers. Deep learning occurred for the mentors as they embraced design thinking.

Based on the research, many implications for 21st century learning practice emerged.

- The adoption of a prototyping mindset creates a bond that enhances the learning experience. It was important that the mentors and middle school students were learning design thinking, something new to both groups, together. Throughout the course of the semester mentors grew to realize that they didn't have to be the experts and have all the answers- powerful learning occurred when they could admit that they didn't know something. They were able to model a prototyping mindset by saying, "We may not know the answer, but we know we can work together to figure it out." Actually practicing a prototyping mindset is something that cannot be explained or read about- it must be experienced. As the mentors and middle school students experienced what it meant to adopt a prototyping mindset together they were able to push the boundaries of learning. Becoming a 21st century thinker requires this sense of resourcefulness. Failure, as it is traditionally defined in learning, must be re-conceptualized.
- Empathy is a critical component of human-centered innovation that should be a part of the instructional design process. The mentors embraced the question "How could they create powerful STEM learning experiences?" This required gaining deep empathy for the middle school students. This happened as the mentors read literature on middle schoolers' cognitive and social skills. Most importantly, however, it happened as they developed relationships with the middle school students. These bonds occurred in a myriad of ways—conversations as the group walked to the playground, questions about the materials, and comments about weekend plans. The care and close listening that occurred as the mentors spent time with the middle schoolers gave them the understandings they needed to design and tailor rich learning activities.
- A bias towards action is an essential part of design thinking. When the mentors were unsure about how to design an activity for the middle school students they didn't sit around and talk. They built prototypes. They had real time constraints that gave them the opportunity to experience a "build to think" mindset. Design thinking is characterized by the mindset of a bias toward action. It was more helpful to try something and learn from what didn't work then it was to spend a long time analyzing, talking, and then finally creating an activity. This ability is an important element of 21st century learning as the world is rapidly changing and fluid, and responsive metacognitive skills are critical.
- Deep and meaningful collaborative work is essential to creating learning activities and a culture of 21st century learning. As the mentors planned their instructional activities and as they engaged in brainstorming with each other and with the middle school students they experienced this kind of collaboration. They generated multitudes of creative ideas. They saw the power of a mindset that deferred judgment and built upon the ideas of others. The sense of positive energy and the development of a team culture were hallmarks of their work. Real, meaningful collaboration is the foundation of transformative 21st century education.
- Establishing strong personal connections is the most important part of being a STEM role model for students. When the middle school students viewed their mentors as people they could connect to, it became easier to envision themselves as someone who could potentially have a STEM career. The mentors presented their own STEM biographies to the students, and were able to show the middle schoolers that they were once young people like them. Fostering these connections is essential.
- The biggest learning was how design thinking provided a frame within which students learned how to be mentors, how to create user-centered learning experiences, and how to share their experiences as developing STEM professionals with middle school students.

Conclusion

In a world of increasing complexity, being able to define the problems worth solving can be the greatest challenge, and the greatest opportunity. Learning to do that is an integral part of becoming an empowered 21st century thinker. Perhaps the most important aspect of the Diamond Afterschool Project is the development of agency—being able to identify what problems are worth solving. By learning the design thinking process and mindsets within the context of STEM-based activities, the university mentors embodied that agency in powerful ways. Design thinking puts ownership of the problem in the learners' hands. The design thinking process offered a way to reframe problems as opportunities with multiple viable solutions. Design thinking provided a frame within which students learned how to be mentors, how to create user-centered learning experiences, and how to share their experiences as developing STEM professionals with middle school students. The mentors and middle schoolers engaged in a process that gave them a scaffold to take risks, celebrate joy in learning and build creative confidence as they thrived within 21st century learning communities.

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