Empathy in Middle School Engineering Design Process

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***Abstract*—This work-in-progress studies empathy in middle-school engineering design pedagogy. A model of empathy in engineering as a core skill, as a practice orientation and a professional way of being that can be taught in university programs has been proposed [1]. Does an emotional intelligence model of empathy need to be taught earlier than at the university level? The engineering design process has been included in the science standards for k-12 schools since 2013[2]. One of the purposes of this inclusion is the ability to reach a diverse population of students by applying real world problems in their curriculum. The design process typically includes the steps of defining the engineering problem, developing solutions and optimizing the design. Although the word "empathy" is not used, these problems are defined from an empathetic perspective as "situations people want to change" of "social and global significance." However, the standards do not discuss how to define a problem or how to teach empathy. In the winter of 2016 a study was conducted to evaluate the influence of empathy-based lessons on girls' interest in science, technology, engineering and mathematics (STEM).**

Some information is known about empathy in lessons. Girls may be more interested if lessons are altered to include an element of caring [3]. Other studies indicate children's empathy increases with type of media provided in lesson (computer versus robot) [4]. The study in this article was a qualitative case study of 50 children, grades 6, 7, and 8, boys and girls in an after-school 4-H Science Club. The lessons were conducted once per week. The lessons were previously conducted in an all-girls after-school STEM program with similar available inexpensive materials. Both schools had similar demographics. The students and coordinators(instructors) were observed, pre- and post-surveys were conducted, and interviews of both students and coordinators were audio and/or video-taped. Although responses varied by lesson, initial results indicate many students and coordinators did not understand the meaning of empathy situated in engineering design.

Keywords----middle school, engineering, design process, after-school science club, empathy

I. Introduction and Background

This work-in-progress studies empathy in middle-school engineering design pedagogy. Researchers have proposed a model of empathy in engineering as a core skill, a practice orientation and a professional way of being that can be taught in university programs [1]. But does should this emotional intelligence model of empathy to be taught in the k-12 realm? And if so, how?

Since 2013 the *Next Generation Science Standards (NGSS)* have included the engineering design process. The design process typically includes the steps of defining the engineering problem, developing solutions and optimizing the design. The *NGSS* states that "providing students a foundation in engineering design allows them to better engage in and aspire to solve the major societal and environmental challenges they will face in the decades ahead [2]." Providing real world societal and environmental problems may also help students connect with their own funds of knowledge and enhances learning. Although the word "empathy" is not specifically stated in the *NGSS*, societal and environmental problems could be defined, from an empathetic perspective, as "situations people want to change" of "social and global significance." Solving these problems may require empathizing, which elevates the importance of the needs of others. However, the standards do not discuss how to define a problem or how to teach empathy.

It is important to understand how students, especially those under-represented, learn STEM in middle school. According to the National Research Council, 2006, interest is identified as a critical factor in predicting future engagement in STEM activities and careers [5]. Fewer and fewer students choose to major in scientific fields at high school and university levels [6,7]. In some areas of engineering, such as computer science, the number of women has declined [8]. Because of the importance to learning and future outcomes, educators are increasingly focused on identifying ways to capture and maintain student interest in STEM. However, research indicates STEM interest declines with student progress in school, especially by the end of middle school. A recent national report by the President's Council of Advisors on Science and Technology recommends experiences be created inside and outside the classroom to inspire youth (age 10-14) interest in STEM [9].

II. Research question, Framework, and literature search

A. Research Question

The research question for the study was, *How Do Empathy-Infused Engineering Lessons Influence Student Interest and Sense of Belongingness?*

B. Framework

The perspective of this case study, framed by empathy and the belongingness component of identity, is transformative. A transformative perspective desires to change how people think and behave [10] about otherness in engineering; particularly how policy is written; curriculum is designed and taught in schools; how businesses interview and maintain diversity in their workforce; and how engineering is perceived and markets itself. The paradigm for this study is socio-cultural interpretivist. Or to say, the intent is to "study 'things' within their context and consider the subjective meanings that people bring to their situation [11]."

Socio-cultural theory informs the conceptual framework of interest, belongingness and empathy. The framework draws upon the Stanford 4D Model (Fig. 1) for engineering design which begins with empathy. The needs of the customer are core to the design definition. Empathizing is defined as "work to fully understand the experience of the user for whom you are designing…through observation, interaction and immersing yourself in their experiences" [12].

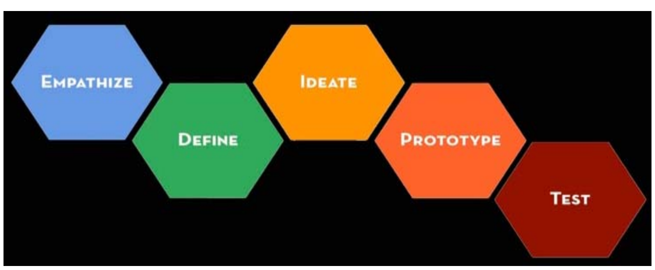

Fig. 1. Stanford Design Model

C. Literature Review

Empathy: Empathy can be emotional, descriptive, or applied (such as, engineering empathic design) [13]. Empathy and caring are also identified as important characteristics for acquiring 21st century skills through project-based learning [14]. However, just requiring empathy is insufficient, since research indicates those who excel in more analytical areas (engineers) are less capable of the emotional aspect of empathy [15]. Other studies indicate engineering educators and practitioners may lack explicit attention to empathy and caring, and a need to prioritize the understanding and the role of empathy [16]. Some information is known about empathy in lessons. Research indicates girls may be more interested if lessons are altered to include an element of caring [3]. Other studies indicate children's empathy increases with type of media provided in lesson (computer versus robot) [4].

III. Methodology

The research was conducted one day a week for nine weeks, within the sixth-grade class of a middle-grade after-school science club program sponsored by the state university through the local 4-H. The school district had a disproportionate percentage of recent immigrants and under-represented minorities. The study was a qualitative case study of fifty middle school students. This work-in-progress reports preliminary results of thirty-eight (38) students (fourteen girls) registered for the sixth-grade class. Approximately fifteen students attended class regularly. Thirteen students provided permission forms.

The lessons were previously conducted in an all-girls after-school STEM program that used similar available inexpensive materials. Both schools had similar demographics. The students and coordinators were observed, pre-and post-surveys were conducted, and interviews of both students and coordinators were audio and/or video-taped.

Any student in the science club could participate in the research. Of the thirteen students who provided study permission, five were boys. Of those boys, two were Caucasian but one was an Eastern European immigrant, two were African-American and one was Hispanic. Of the girls, one was African-American, two were multi-racial, two were Asian, two were Hispanic, and one was a Pacific Islander. All student participants were identified by self-selected code names.

Two 4-H coordinators facilitated the program lessons. Miss Wonderland (code name) was a female Caucasian in her early 30's, educated as a special education teacher, and had facilitated 4-H classes for four years. Miss Sweet (code name) was a female of Pilipino descent in her mid-20's and a recent STEM graduate. The third coordinator was a post-doc in science education conducting longitudinal research at the school.

A. Data Collection Methods

To address our research questions, we utilized qualitative methods, often called interpretative phenomenological analysis (IPA) [17,18] in engineering education, so we could best unveil and understand how students responded to empathy-infused lessons. Instruments included open-ended student surveys, lesson observations and coordinator interviews.

1) Student Surveys: Open-ended student survey questions were on STEM topics, STEM careers, belongingness and empathy. Fig. 2 is an example of the 5-point Likert scale part of the survey. The survey was conducted at the beginning and end of the nine-week program.

SURVEY					
How much do you like finding out about the following topics in or out of school?					
	Like a lot	**Like a little**	**Neither like nor dislike**	**Dislike a little**	**Dislike a lot**
How stars and planets form?					
Mixing materials together to see what happens.					

Fig. 2. Sample Survey Questions

2) Observations of Lessons: Students' level of engagement, content of drawings, and language utilization were observed in student conversations and written work with an observational protocol. Field notes were taken and the student lesson notes on empathy were studied. All the lessons were borrowed from various STEM websites with a "STEM Save the World" focus and followed the Stanford Design Model (Fig. 3). Lessons required both individual and group work, and were intended to evoke comments about empathy and how a feeling of empathy might influence design or interest, and a sense of belongingness.

LESSON NAME: Live Like an Animal
SOURCE: eGFI-For Coordinators
BIG IDEA OR CONCEPT: STEM Saves the World!
DAY ONE:
Background: When engineers use examples from the natural world to influence their design they call it "biomimicry."
Real World Connection: The 2008 Beijing Olympics main stadium is an example of this type of design. Architects and structural engineers who built it designed it to look like an enormous bird's nest.
Intro to lesson: When you were younger, did you ever build a fort out of pillows, a blanket, cardboard, or tree branches? Can you think of an example from nature that resembles your fort? What kind of animal structure is similar? (Bats or bear cave, bird's nest?) What are some advantages of the examples given? (I.E. lightweight, strong, sheds, protection).
Activity: In self-selected groups of three to four the students are going to design a human structure based on an example from the animal kingdom they pick. The animal will be researched for ways that animal finds/builds their own shelter. Using that information, the students brainstorm ideas and design a human structure that incorporates some of the useful features of the animal shelter and sketch and model to the sketch their structure with dimensions and identify needed material.
DAY TWO:
Intro to Lesson: Ask the students, "Why do you think an architect or engineer would model a building or other structure to the animal and
natural world? How do you think you might feel about biomimicry if you were the animal?"
Activity: The students will recap this week's STEM challenge, present their design, discuss what was improved and identify any inspirations.

Fig. 3. Typical Lesson Plan

3) Student and Coordinator Interviews: Interviews were conducted by protocol and recorded with either audio or video tools depending on size of group. Fig. 4. depicts a section of the coordinator interview.

Coordinator Interview Questions

- What do you think of the lessons? How do you think empathy fits in?
- Do you think there is a difference between girls' and boys' understanding of empathy from the beginning to the end of the program? Do you think they have a better sense of empathy?
- Do you think it was more important or relevant to girls versus boys?
- Was it important for students to feel they belong?
- Do you think students understanding the design process better and the important of empathy in that process, after this program?
- Do you think that empathy-based lessons have increased students' interests, boys versus girls, in STEM?

Fig. 4. Coordinator Interview Questions Example

B. Data Analysis

The overall coding approach most closely resembled what Saldana describes as in vivo, descriptive, and emotional [19]. A constant comparative method of data analysis will be utilized, comparing "one segment of data with another to determine similarities and differences" [20]. Documents will be coded a priori for the three constructs of empathy, interest, and belongingness by evaluating words, emotions, and emotional intensity [21]. All documents and artifacts will also be simultaneously open-coded for concepts outside of the *a priori* set so no concepts will be missed.

IV. PRELIMINARY FINDINGS AND DISCUSSION

Although preliminary findings suggest empathy-based lessons may influence student STEM interest and belongingness and may be gender-blind, analysis is incomplete.

Analysis of the photos, audio and video data of all lessons and artifacts must be completed to confirm any overall trends of interest evolution, sense of belongingness, and empathy understanding. However, the preliminary analysis of the interviews, open-ended surveys and observation field notes indicate students may better understand the meaning of STEM and STEM career options after the lessons than before. When asked if there was a specific activity of interest in STEM one student originally said, "exploding things," but after the program said, "In technology I like it because you get to make apps and other cool things. Also, engineering because you get to make things like robots," indicating a broader understanding of STEM.

Additionally, preliminary results also indicated students may have a clearer understanding of the connection between engineering and empathy after the lessons. For example, John Cena (code name) was asked, "What is engineering?" John's initial response was "building stuff," but he later indicated an added sense of empathy. "It is about thinking about building something and thinking about who you're building for."

Examples from the coordinator interviews addressed the need to clarify the concept of empathy, especially engineering empathy in instruction. One coordinator said, "They didn't always think about it right away and I would have to hint some things but automatically they would relate it to a real-life structure, tool, or situation." Another coordinator expressed concern about the lack of framing/scaffolding of empathy and the design process in the lessons. "We, [the coordinators], should have provided examples of places people couldn't get, you know, [examples of] how do you think this would make somebody feel."

The coordinators believed empathy should be infused into lessons. They were less certain how to connect emotional empathy to engineering design empathy and how to assess student progress other than through student self-reporting. Both coordinators and students lacked instruction in empathy and its relevance to engineering design. Students did not seem to understand the connection between empathy, empathic design and the design process. When students were asked in their interviews what they learned about the design process most did not recall it. Coordinators lacked confidence in any instructional methodology to scaffold student learning of those connections.

Although professional development and curriculum changes seem necessary, some minor improvements to the lessons, like varying methods of assessments and instruction to increase student participation may be logical first steps. Students participation in writing and drawing on worksheets was minimal but all students begged to present their designs orally.

V. Implications

Desired implications from this study are to inform future curriculum design, advance research and practice regarding increasing the number of students from under-represented populations interested in and persisting in engineering fields. Additionally, this work seeks to transform the reputation of engineering and reveal its nature as an empathetic profession. Our hope is by highlighting empathy in k-12 curriculum, especially in analytical sciences, and elevating the status of the caring sciences, engineering will be perceived as a more welcome culture where everyone feel they belong.

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