Exploring Humanitarian Engineering Senior Design as a Community of Practice

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Humanitarian Engineering (HE) is an emergent subdiscipline of engineering, where teams design to improve the wellbeing of underprivileged communities. As HE begins to become a topic relevant to undergraduate programs, opportunities arise to understand the sociocultural learning that happens on Humanitarian Engineering Senior Design (HESD) teams. This preliminary study uses the Communities of Practice (CoP) framework to establish a foundation for both understanding this learning and continuing to research HESD.

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Introduction

Humanitarian Engineering (HE) plays an important role in and outside of engineering programs. Outside of programs, teams design to improve the wellbeing of underprivileged communities[1]. Within programs, on Humanitarian Engineering Senior Design (HESD) teams, students practice skills that are often overlooked in engineering, such as transformational listening and generating empathy[2]. Engaging in HE design allows for design programs to redefine "innovation", as faculty and students recognize that new, disruptive and significant designs need not follow American values of being expensive, fast, or "high tech"[3]. HESD programs may offer insights for the larger engineering education community, particularly in the areas of international collaboration, and professional formation of engineers.

Important to note is that though HESD projects have these properties, projects can differ from the way that HE should be practiced. HE requires the ability to listen in context, and deliberately uses social justice as a framework to understand the impacts of engineering design. Traditional engineering students do not start their design projects with these skills, and they can be overlooked as HESD projects progress[4]. HE frames communities as collaborators to design *with*, as opposed to the traditional framing of communities as users that must be designed *for*[5]. HESD is normally framed to be for the benefit of the communities involved, but, student's learning - particularly Western students - is usually the top priority[2]. HESD can offer unfortunate potential for white saviorism, "a sense that we as Westerners have the unique power to uplift, edify and strengthen"[5].

The HESD group investigated for this study is within the Virginia Tech (VT) mechanical engineering program. The ME senior design program at VT has historically consisted of faculty-sponsored projects and industry partnership projects, usually with local corporations. More recently, to accommodate the unprecedented growth of entering classes, VT began developing options for HESD projects. HESD projects have spanned multiple countries and technical concentrations, including medical devices, agricultural tools, well drilling, and sanitation. Establishing these HESD efforts as a CoP is the first step to understanding the unique skills that HESD teams learn.

Theoretical Framework

We use Communities of Practice (CoP) as our theoretical framework for understanding the learning that occurs in HESD at VT. The CoP framework extends learning beyond concepts and behaviors, and defines learning as becoming a functional member of communities. Learning is dependent on the relationships between people, the customs and practices of people, and the identities that are demonstrated through those relationships, customs, and practices. These factors are present in engineering environments, though their significance can be overlooked. For these reasons, CoP is an appropriate lens through which to examine the sociocultural learning that occurs in HESD. Ultimately, the CoP framework can help educators design curriculum with reference to "real life" engineering and authentic engineering identities, rather than engineering as a idealistically rational and assumedly non-social practice, which are unfounded assumptions about the nature of engineering work[6].

To begin to understand the socio-cultural learning that happens in HESD, this preliminary study asks the following research question: *In what ways does*

humanitarian engineering senior design show characteristics of a Community of Practice? To guide our approach, we use Wenger's characteristics of a CoP[7,8]. A CoP may not necessarily have all of these characteristics, but should have many of them. As students are integrated into the world of engineering through the design process, the students, their advisors, and others involved in senior design, may demonstrate characteristics of a CoP.

Methods

Working with the director of the senior design program at VT, students from senior design teams were purposefully sampled to include diverse projects and team contexts. While this study focuses on HE projects, students from non-HE teams were also purposefully sampled to compare and contrast HE teams with the larger SD community. Researchers did in person recruiting before inviting participants for interviews, and submitting design artifacts, which both served as sources of data for the study. The research protocol was approved by the VT Institutional Review Board.

The role of the researcher significantly impacts approaches to qualitative inquiry, and it is imperative to acknowledge the researchers' relation to HESD[9]. To this end, we acknowledge that all researchers are members of the HESD community at VT. However, no researcher recruited or interviewed students they were advising, and in data collection researchers only had the relationship of "researcher" to participants in this study.

The sources of data used to inform this preliminary study are design artifacts offered for research, and four interviews with senior design students - 3 from HESD teams, 1 from an industry team. Using a semi-structured protocol, interviews were conducted in person as well as over skype and phone, lasting from 30 to 60 minutes. Interviews were audio recorded, transcribed, and then coded using a priori coding, each code representing a characteristic of CoP. To improve trustworthiness of the results, researchers normed on code definitions by finding mutually agreed upon examples from the data before applying codes[10].

Results

Our preliminary data suggests that HESD has many of the features of CoP. Examples of many characteristics coded from interview data are shown below in Table 1. To avoid redundancy, we have grouped our discussion of the CoP characteristics into four distinct groups: 1) Relationships, 2) Identities, 3) Tools, Jargon and Shortcuts, and 4) Assessing Appropriateness. Each of these groups contains characteristics of Wenger's CoP

framework. These are not mutually exclusive, but rather there is significant overlap in the characteristics[7].

CoP Characteristic	Evidence from Interview Quotes
Relationships	
Sustained Mutual Relationships	*kind of like an hour or two of time when we're together and we're able to work towards a common goal at that point. And we get to go to a pool or.. .just kind of drive around. It's- yeah. It's good bonding.*
Shared Ways of Doing Things	*For example, they missed, one week they missed three meetings. They're not really participating. So they'll do what you ask them to do, but beyond that there's no real contribution. It just seems like - actually she's missed four meeting - it's just missing meetings. Not really contributing during those meetings.*
Shared Stories and Knowing Laughter	*I tell people about jello babies and they're like "okay that's fun can I see the jello babies?" and they'll talk about what they're doing for their senior design. And that's generally it....General amusement and commiseration.*
Shared discourse & perspective of World	*By the end of it we hope we will have like a deliverable project. In the end means May, since that's when graduation is. So hopefully by the end of May or by the end of the school year you will have something that we can actually ship off that's functional and appropriate for [the community's] needs.*
Knowing what others know	*so we basically communicate by email or text message...if we have questions, we collect them in a google drive and then like every second day...one of us writes one of the hospital coordinators in malawi. So that's not my job, basically, because we have another guy who's texting the client all the time.*

Identities	
Mutually Defining Identities	*I think, ultimately what [our client] wants carries the most weight over what we think. And it also helps that he is an engineer. So we put a lot of stock...what he's saying comes from both what he wants but also his technical background.*
Tools, Jargon and Shortcuts	
Specific Tools	*But say, oh you can decide on three designs by using this table or this matrix or this tool. I think these matrices in general are really good because you look at your designs analytically and try to as least biased as possible.*
Jargon and Shortcuts	*And then we talked about what we have done from Sunday to Wednesday. And, for example, we need CAD models for the PDR tomorrow. And then tried to like set up our slides for that.*
Assessing Appropriateness	
Ability to Assess Appropriate-n ess	*last year's design had like a contact in the biochemistry department I think for pathogen testing. So to have like an objective statement on how many pathogens are killed using the washing machine.*

Table 1: Evidence of CoP Characteristics

Relationships

Sustained mutual relationships in HESD, which emerge from mutual engagement with the work at hand in a CoP, were evident from participant interviews. Students' sustained relationships with each other were most obviously demonstrated through their consistent meetings at least twice per week. Students talked about relationships with their teammates fondly, praising and appreciating each other's work. They also talked about non-harmonious relationships, demonstrated by the following student quote: *"the other two guys ... I don't know how to handle them really good. We always try to give them something to do for the next meeting, but then at the next meeting it always seems like they...thought about it like ten minutes before"*.

Other relationships exist as well. Students discussed their relationships with their advisors. Faculty advisors and industry partners were recognized by students as having legitimate engineering knowledge to pursue. They also were responsible for assessing student's presentations of designs during the design review. Because of this we identify them as the core group of the CoP.

Identities

Through the CoP framework, Wenger[7] discusses identities as "anchored in each other and what we do together" (p. 89). Our data demonstrated mutually defined identities that were strongly tied to students' positions in the HESD CoP. In particular, students identified with the work that they did for their team. One student identified as being part of "the heat transfer subteam," which also meant not "[knowing] how vibrations [sub-team] is." Students also had individual identities within their HESD teams. For instance, one international student described his role, defined mutually by his team and himself, as the "theoretical person" because of his international student status.

Tools, Jargon & Shortcuts

Tools, jargon, and shortcuts were all used heavily by the HESD CoP. Students described the many charts and tables they used as "tools", used to make decisions and provide insight about their designs. The use of these tools was expected by the core group of faculty. For example, a risk assessment protocol, referred to as RAMP by students (short for Risk Analysis and Management for Projects), was used by each team for the preliminary design review (referred to as the PDR).

Assessing Appropriateness

The mid-semester design reviews are one way that appropriateness is assessed in the HESD CoP. The core group of faculty used rubrics to assess students' presentations of their designs. Students also discussed the ongoing assessment that occurred outside of the PDR. Students would refer to HE advisors and their Senior Design advisors for feedback about the appropriateness of students' ideas. Finally, students use of the RAMP tool, discussed in the previous section, indicates that students also had some ability to assess and determine what were appropriate design decisions.

Summarizing HESD as a Community of Practice

To summarize our findings for our study, which explored the ways in which HESD demonstrates characteristics of a CoP, we offer Figure 1. Our data suggests a core group within the HESD CoP composed of Engineering representatives from industry. This core group remains fairly constant over time and consists of faculty advisors and clients from industry. Additionally,

this core group has the most influence in negotiation of meaning in the Community of Practice, as they determine how students are graded and do the grading. They have the final say of whether or not a design decision is appropriate. Our data also supports the existence of a group on the periphery, composed of non-industry clients and design advisors in the HE space. While HE advisors represented a field of knowledge that was relevant to students' designs, sometimes representing the community of stakeholders that students were engaged with, they were not necessarily framed as role models or as representatives of the fields that students would enter. From an advisor point of view, HE Advisors did not have control over the way that designs were assessed.

The CoP of HESD is not necessarily distinct from senior design as a whole, though it involves the HE community, which other areas of Senior Design do not. Acknowledging the participatory nature of our research, the diagram is from the perspective of those participating in HESD. Those outside of HESD may not view the CoP in the same way. More research is needed to elaborate on the ways that HESD interacts with non-HESD.
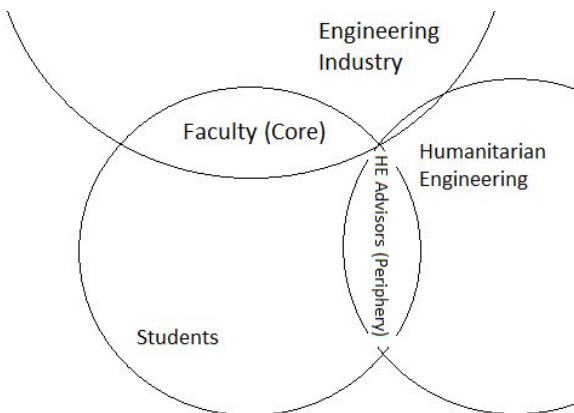

Figure 1. HESD as a Community of Practice

Discussion and Future Work

This work explored HESD through the lens of Wenger's CoP framework. Some of the most notably present CoP characteristics in the HESD CoP were a shared discourse and perspective about the world, mutually defining identities, and tools. We also begin to understand the shape and nature of HESD as a CoP, with faculty representing industry as a core group, and HE advisors on the periphery. This work demonstrates the potential for CoP in understanding HESD.

However, our conclusions do have limitations, including the number of students interviewed and the lack of interviews with HE and non-HE advisors.

Additionally, this study only captures a few short moments of the brief, but rich, history of HESD at VT. Future work will expand data collection, focusing on students' trajectories through the HESD CoP and sociocultural learning outcomes associated with HESD. Wenger[7] notes that sociocultural learning must include "sustaining the interconnected Communities of Practice" (p. 8). Undoubtedly, this work supports the presence of distinct but connected communities of senior design, engineering industry, and humanitarian engineering. Echoing Khalil[8], we argue that aligning HESD learning outcomes with the larger senior design and industry communities may foster "common goals, gained trust, and changes in attitudes" (p. 46). Future work will aim to enlighten practice with research, intentionally connecting the three CoPs for the sustenance of all.

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