Broadening Engineering Perspectives by Emphasizing the Human Side of Engineering

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In the present day, most engineering programs are focused on imparting highly detailed technical knowledge to their students. Some of the forward-looking programs and faculty are bringing socio-technical perspectives to engineering education, but to- date they are not the majority. Though the students remain interested in technical content, oftentimes they face difficulty connecting what they learn to practicality. Consequently, students resort to learning through memorization and example-based learning implying that students quickly forget what they have learned. It is well documented that students can retain more about courses where they have participated in team activities, problem solving, etc. Since they can work on connections and sharing ideas as a community. In recent years, it is also becoming apparent that a lack of attention to human values and the human side of engineering will create disconnects between the social responsibility of engineers and their place as technical citizens and leaders. However, if a connection exists between the students' education and their personal learning goals, would there be an improvement in how they learn? Through our work, we seek evidence that when a student engages personally and is socio-technically aware they are more receptive to learning. We would like to know if incorporation of a human sided approach to engineering (through an inquiry classroom), enables engineering students to be more engaged and involved in their learning and eventually towards societal issues. Additionally, we will perform a content analysis of student reflections to investigate if an inquiry-based environment is suitable for students to engage in the human side of engineering.

Index Terms—Inquiry, Human side of Engineering, Reflection, Freshman Engineering

I. Introduction

ENGINEERS play integral roles in all technical organizations. However, by focusing on specific technical roles, engineers can often lose focus towards the big picture, neglecting the impact of their work on the society/users, which is an important responsibility of engineers. This is emphasized in many engineering societies' codes of conduct. Thereafter, to be a part of future technological developments, engineers need to learn how to connect and appreciate all human endeavors, even their own, thus engaging beyond technical aspects. It is expected that technological shape shifters, those who understand the values of social reality and technical competencies, will be better positioned to face the sociotechnical challenges of the future developments. Can early engineering curricula facilitate students/future engineers inculcate some of these behaviors?

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Many conventional engineering programs focus on imparting skill-based technical knowledge to their students without emphasizing relevant social aspects. Though the students remain interested in the general subject area and learn to be highly skilled, oftentimes the lack of practical relevance, feeling of being part of a race (competition) and learning through memorization implies that students quickly forget what they have learned and cannot advance to the right level in the future related courses. Research has shown that students can retain more about courses where they have participated in team activities, problem solving, etc. [1] – [3]. Is it possible that when students try to engage at a personal level, they are better positioned to learn, care about their education and form a better verbalization to progress in their careers?

A. Research Questions

It is becoming apparent that a lack of attention to human values will create disconnects between social responsibility of engineers and their relationship with society [4], [5]. Our main research question is if incorporation of a human sided approach to engineering classrooms will bridge this disconnect. The classroom will create a safe space where the human behind the engineer feels valued and included and cares about his/her work, the team and his/her learning. Thus, we attempt to fill the void of social responsibility created by focused curricula in many engineering classrooms. To evaluate our progress, we will perform an analysis of students' in-class reflective activities to investigate if our classroom environment (inquiry-based) is suitable for students to recognize the value of human attributes in technical courses.

II. Human Side of Engineering in Classrooms

Human side of engineering, as defined in [6], is a means of understanding society and the engineering implications to society. However, to understand society, one needs to begin by understanding oneself and their role in society. Imbibing human centric values through the course of engineering education implies that students have trained to learn with the end user in their minds.

In order to incorporate human centric education in a classroom environment, students need to understand why they are learning something, how it connects to who they are and how their learning process and knowledge can enable them to contribute to society. These objectives are rarely emphasized in engineering classes though they are the core reasons behind the students' presence in engineering classrooms. For students to engage in the human side of engineering they need to start by understanding their motivation and learning styles and follow up by interconnecting these in their everyday classroom education.

In our courses, we have observed several aspects that motivate students to learn. We broadly classify them as:

- Self driven – When students/people feel that their own work is valued/appreciated
- Community Impact driven – When students/people feel that they have a social impact/can influence others
- Example driven – When students/people feel inspired by the work of others and seek to do better

It must be noted that each of these aspects is unique to the individual students' background and experiences. Moreover, it is well studied and documented that the process of learning is often personalized and selective to patterns defined in early education programs. It is observed that as students progress through years of university education, they learn to be more adept at understanding the university system and optimize/adapt their learning process and practices to obtain required grades. The pace and content introduced during university education leaves many students trapped between two choices, learning deeply with meaningful connections or excelling to receive good grades.

The question of how we learn is not regularly discussed nor introduced in engineering programs. There are very successful exceptions in more than few schools, however, the large programs are usually focused on the disciplinary material and needed expertise in Physics, mathematics, and subjects that are essential to engineering programs.

In the last two decades many schools are changing their classroom experiences based on many engineering education research findings. However, to this date most schools cannot afford to spend much time on exposing students to the details of how they learn. Students' learning process, and ability are evidently based on their qualifications to enter the competitive programs. However, research shows that there are needs for better education processes, and better curriculum designs that are informed by the process of learning [7], [8].

To obtain an intersection between a student's motivation, learning styles and detail of university courses, we need to understand the impetus behind the students will to learn and create spaces for them to engage in learning. While sociotechnical motivators were a major driving factor in the past several decades, present-generation students are far more privileged and have more opportunities to pursue fields of their interest. In such situations, the role of universities extends beyond providing basic education. Universities need to make sure that the student not only maintains interest but also finds means of furthering his/her interest through the chosen vocation. At the same time, the student should be able to contribute to the advancement of the vocation. In order to fulfill these different objectives, classroom instruction needs to transform, providing students a platform to voice their thoughts. The class needs to provide an open and an encouraging space for students to be themselves. They need to have a safe and inclusive space where they can examine, exchange, and reflect on who they are and how they can find a belonging to the field of study and future professional practice. Can present-day classrooms transform into such environments?

To maximize the students' learning and success in an educational setting, some methods such as inquiry-based learning, team-based learning, project-based learning, POGIL [3], [9]– [12] exist and have had varying levels of success. One may argue that the success level of each of these techniques would inherently tie-in to the students' learning process, often considered personalized. While this may be true, it is observed that when students are completely engaged, not just technically, they are deeply motivated, seek to learn more and are able to attain self-actualization [13], [14]. Thus, in our work, we attempt to understand that given a safe space and a classroom environment (inquiry-based) to connect who they are with what/how they learn, will students become better socially responsible learners? This is a combination that we term as the human-side of engineering in a classroom.

III. Inquiry-based learning

In this paper, we present our observations for students in an inquiry-based class while they attempt to understand how they learn and apply it in a team environment. These students are from a freshman-engineering course and a majority of the students have stated that they want to make a difference in the world. The course is based on the principles of Deweyan inquiry [15], [16] and emphasizes the learning cycles of the student. It is known that freshman engineering courses are formative towards students choices of major and learning interests through university [17]–[19]. It is hence vital to allow students to explore learning methods and engage socially with a community of learners in their freshman year.

In an inquiry-based cycle of learning, the student is at the center of his/her learning. The student learns to make choices and decisions while problem solving and seeks to improve. It is also necessary that the student identifies early on what works best for his/her learning and deepen their processes throughout the four-year program. However, the impact of a team or a community of learners in an inquiry-based environment isn't well defined. It is expected that engagement with a team or community of learners provide them with a sense of support, not only as a psychological need [20] but also as an essential step towards self-emancipation. But, does the community help students share their learning vulnerabilities and learn with one another? This is another attribute that we consider when examining the impact of human side of engineering in an inquiry-based classroom.

In an inquiry-based classroom [21], every student is expected to engage in cycles of learning. The entry to the cycle is defined solely by an individual's personalized experiences and especially when facing difficulties. Once in the cycle, students can choose their own paths to proceed and this ideology aligns well with the basic idea of the human side of engineering, knowing oneself.

As illustrated in Fig. 1, the Deweyan cycle of inquiry involves five different stages. The first stage is a felt difficulty, followed by identifying/locating the source of the difficulty, proceeding to find solutions, forming beliefs/disbeliefs and re-entering the cycle by questioning beliefs/disbeliefs. As the student progresses through the different inquiry stages, the process becomes second nature and a part of their learning process. However, what we have observed is that before engaging in the cycle of inquiry or adapting it, as a process of learning, the student needs to feel ready. This readiness is driven by several factors though most importantly, a sense of belonging/community is considered to be crucial. Thus, we propose an additional layer in the inquiry-based learning mechanism that involves the self, who needs to be motivated, should be able to communicate and is surrounded by a community of learners. We hope that such individuals are better prepared to enter meaningful inquiry cycles and enrich their overall learning experience by engagement with their peers.

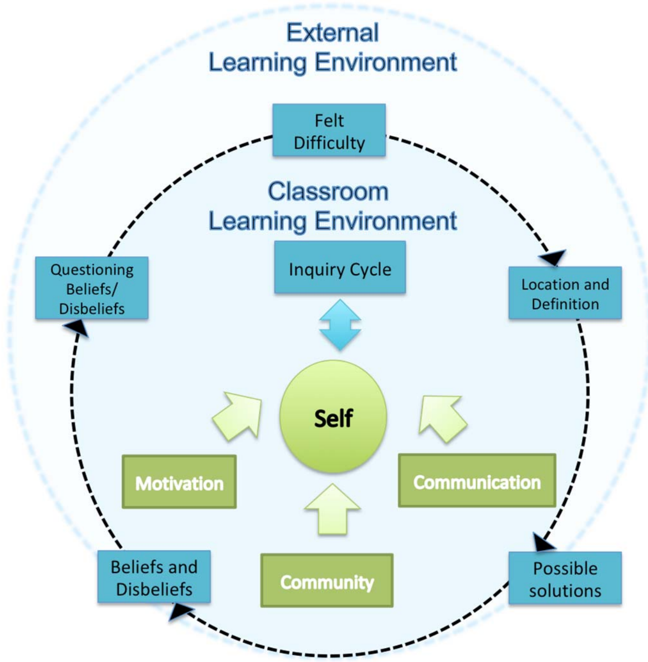

Fig. 1: Representation of Deweyan inquiry cycle involving factors driving self prior to entering inquiry. This is an adaptation created to incorporate the human side of engineering in a traditional inquiry cycle

A. Reflective Activities

Our course has the strong focus of human side interpretation of Deweyan inquiry. The instructors are invested in the students learning, they care about their growth and constantly interact/provide feedback. For the research study, in-class reflective activities are analyzed at different time points during the semester. We have tailored the reflective activities such that the students can explain their own learning processes while interacting with their peers. It must be noted that such reflective activities are done in every class and we consider them to be integral to the student's ability to engage in inquiry cycles. The reflective activities are community activities; students can interact with other students at their desk or ask questions to the instructor. The activities are for approximately 10 to 20 minutes. The students aren't expected to have a perfect final solution. Instead, they are expected to share their work, thought process and details of how they would approach the problem.

In this assessment, we have asked students three questions to understand their readiness, their learning style, involvement in the process of inquiry and impact of their learning community. Since the course emphasizes their learning process and self-driven inquiry, through these reflective activities, we seek to know if students are able to engage at a personal level with their learning. Specifically, is the inquiry-based environment suitable for the students to successfully engage in their human side? The four questions selected for this study are:

1. What do you wish to be after finishing this program?
2. How do you learn and study?
3. Do you prefer learning as an individual or in a team?
4. What did you learn in this class?

These questions were selected to first understand the students' motivation to learn, followed by their learning process and finally the impact of the course on their learning process. The first two questions were asked at the beginning of the semester and the last two questions were asked towards the end of the semester.

IV. Results and Analysis

We use a content analysis technique to analyze the qualitative data obtained from the in-class reflections. We identify common themes, ideas and patterns for each of these questions and then categorize them into certain broad categories. Our first question was to understand the students' background and their interest, why did they come to this program? We performed this study on reflective activities from approximately 40 students and the data was collected between Spring 2018 - 2019.

As seen in Fig. 2, we find that almost 50 percent of the students want to contribute in some way to the technical profession, with responses varying from engaging in specific technical industries such as the power industry to next-gen technology in robotics, medicine and defense. A small percentage (below 15 percent) want to pursue research and graduate school. A large percentage (about 30 percent) are open-minded and are expecting that they will benefit from the program and the courses will help in alignment of their learning interests.

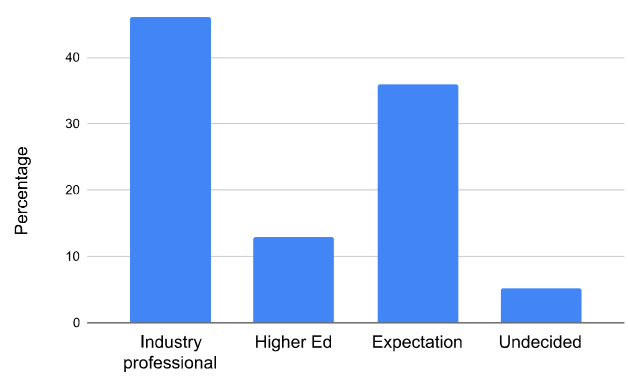

Fig. 2: Broad categorization of area's students wanted to be in after graduation

Next, we asked the students about their learning processes, Fig. 3. Almost 40 percent of the students responded that they learned by repeated practice or following examples. A large percentage also repeated that they learned visually. Only a small percentage of students (below 15 percent) stated that they learned interactively or through hands-on activities. This led us to conclude that students were indeed in the phase of memorizing and not making deep connections between themselves and their education. Additionally, they weren't tapping into the resource of their classmates.

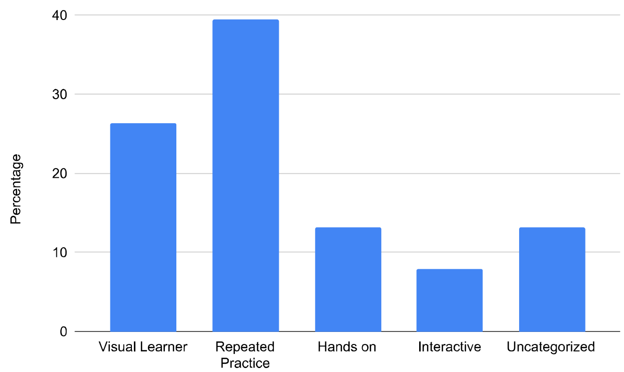

Fig. 3: Summary of students' responses on how they learn

Over the course of the semester, the students participated in several in-class reflective activities. They interacted with their peers in labs, discussed their ideas and thoughts. We encouraged them to find their preferred learning style, friends/a team to learn with, etc. The inquiry cycle was also emphasized through the semester. To assess the impact of the in-class inquiry environment, we further asked the students if they preferred to learn in teams/individually.

Fig. 4 shows that almost 60 percent of the students responded in favor of a team environment since it helped them share ideas with one another, learn from different perspectives, and see something beyond their narrow vision. Many also mentioned that the team size mattered since they would get distracted in large team sizes and in those situations they preferred to learn by themselves. This was a clear improvement compared to the limited interaction at the start of the semester.

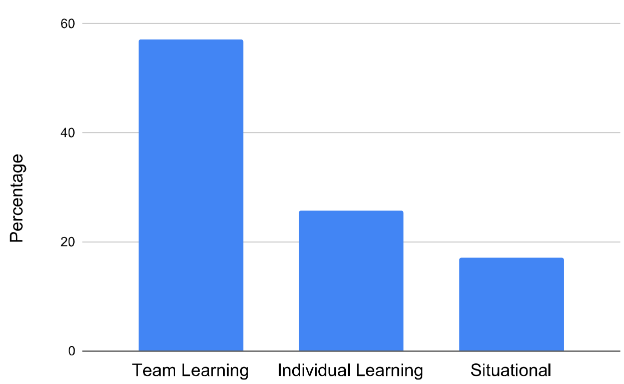

Fig. 4: Summary of students' responses on how they learn better

Finally, we followed up this activity by asking students what they had learned in the freshmen-engineering course. We wanted to know if the students had learned some aspects beyond the technical content. As seen in Fig. 5, almost 40 percent of the students responded that they learned how to learn. They mentioned that they had learned to problem-solve, critically think about problems, work in teams and share perspectives and also learned to make mistakes. About 25 percent expressed that they had learned skills of critical thinking and would continue to use them in other upcoming classes.

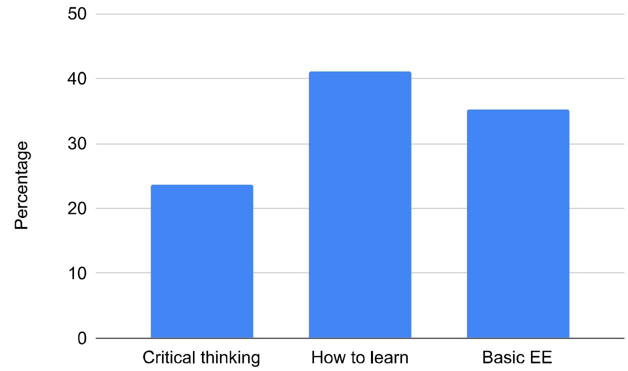

Fig. 5: Summary of students' responses on what they learned in the class

In addition, approximately 35 percent mentioned that they learned basic concepts about vectors, trigonometric identities and matrices and hoped to use these in upcoming classes. Finally, it must be noted that we performed this analysis over variable population sizes in consequent years and found consistent results.

V. Conclusions

In the environment of our inquiry-based freshmen-engineering course, we attempted to understand if incorporation of a human side approach was beneficial to the students' learning. We first identified the impetus behind the student's presence in the classrooms and then proceeded to understand how they learned. Initially, a large number of students reported that they learned by practicing or visualizing. Only a small percentage acknowledged the interactive aspect. However, at a later time point when the students were asked if they preferred to work in teams, they largely agreed since they had learned to appreciate the interactive nature of sharing ideas. Finally, when the students were asked about what they had learned in the course, a large percentage reported that they had learned how to learn. These results have shown us that by incorporating a human centered approach in our classrooms, students are indeed able to learn beyond the technical content. They learn the skills of teamwork and critical thinking and feel the need to engage in a community of learners.

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