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Designing a multi-cycle approach to empathetic electrical engineering courses

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Designing a Multi-Cycle Approach to Empathetic Electrical Engineering Courses

Abstract

Background

The ability to empathize provides the basis to understand others, an often-overlooked professional skill in engineering curriculums. Studies have shown that engineering students have less empathy after completing their degree than when they had entered. Having low amounts of empathy in engineers can result in less concern for public welfare and social considerations during the engineering design process.

Purpose

In this work, we consider when engineering students are entering an empathetic cycle. Most studies develop a model based on an educators' perspective and how empathy is a teachable and learnable skill. This study examines how engineering students can enter, sustain, and improve their cycles of empathy.

Design/Method

A qualitative approach is taken to compare and contrast the end-of-semester reflections from students in engineering and design. Coding, an ethnographic research method used to find thematic patterns and similarities throughout documents, is used to analyze end-of-semester reflections from students who have taken courses in electromagnetism for electrical engineers, electromagnetism for non-electrical engineers, and an industrial design course with a focus on engineering and technology literacy for designers.

Results

We propose a multi-cycle model of empathy in engineering that identifies self-awareness as the first step to empathy through the cycle of inquiry. Our model incorporates existing models of empathy in design, and empathy in engineering that introduces mode switching.

Keywords

empathy, emotional intelligence, EQ, cycle of inquiry, electrical engineering, engineering education, student-centered, reflective practices, design, industrial design

Introduction

As electrical engineering students transition from school into industry, they will face new challenges where globalization, sustainability, and social responsibility will be at the forefront of design through a human-centered lens [1]. It is important to cultivate diversity and inclusion in higher education so that graduates enter the industry with more globally aware, human-centered skills needed to fulfill such a future. We believe the key to fostering such attitudes starts with empathy. However, previous work has shown that engineers' empathy decreases as they progress through their undergraduate studies, leaving university with low levels of empathy [2]. Newly graduated engineers are thus ill-equipped to enter the professional industry.

We look at previous studies that aim to integrate empathy into engineering [3], [4], [5], [6], [7], [8] while considering the field of industrial design, where the incorporation of empathy into the design process is well established and studied [9]. This study, as our team's first study in the series of investigations on empathy, will look at how students are able to enter the cycle of empathy through the process of inquiry. Our research draws from the fields of psychology, neuroscience, engineering, industrial design, and education. We combine this research with data drawn from three classes: electromagnetism for electrical engineers, electromagnetism for non-electrical engineers, and an industrial design course with a focus on engineering and technology literacy for designers. By analyzing the differences in this data, we draw comparisons between electrical engineers, non-electrical engineers, and industrial design students in order to propose a model of empathy in engineering.

Emotional Intelligence and the Educational Setting

Individuals with emotional intelligence, or EQ, benefit from being more self-aware, have more empathy, and have greater motivation [10]. EQ is comprised of five key elements: self-awareness, self-regulation, motivation, empathy, and adeptness in relationships (social skills)[11]. These traits are further magnified when individuals with high EQ work cooperatively in teams. Multiple teammates possessing these skills brings out the best in others by increasing feelings of self-worth, which in turn increases productivity and desired outcomes [12]. Emerging research shows that when someone imagines themselves doing something that someone else is doing, a set of neurons light up called mirror neurons [13], [14], [15]. Mirror neurons are thought to be the neurological basis for empathy and are based in imagined mimicry. Therefore, we infer that in an educational setting, students gain empathy when they detect and mimic the empathy of those around them, including faculty members who model empathy through their teaching practices.

We define an effective teaching practice as combining a dynamic inquiry approach with an interpersonal approach to improve rapport between teacher and student. Meyers [16] indicates that an effective strategy on improving rapport includes:

1. Communicating respect, interest, and warmth toward the student
2. Speaking with the student outside of class
3. Focusing on the student's feelings.

The full extent of empathy cannot be reached without self-awareness and emotional regulation [15]. Self-awareness allows the capacity for self-other differentiation, while emotional regulation allows the individual to have empathic concern when faced with another person's emotional state [17]. How then can we detect empathy in engineering students? Previous work by our team has proposed a framework for incorporating the cycle of inquiry into curriculum [18] and has linked the cycle of inquiry with increased self-awareness [19]. We take this work one step further by positing that the first stages of empathy are signaled by an increased amount of self-awareness in students [15].

Self-Awareness: A Product of Inquiry and Reflection

A student's sense of motivation is deeply connected with their self-awareness [20]. D. Scott Ridley theorizes that a student's motivation to act is based heavily on one's conception of self and on higher order processes - specifically reflective self-awareness, emotion, and volition. When a student is presented with a challenging academic task, a student who cares about their learning will invest more time in conscious thought, emotive concern, volitional contemplation, explicit goal setting, and deliberate action toward doing well [20]. Thus, to be self-aware is to be conscious of your beliefs, values, strengths, and limitations.

Reflective practices [21], [22] allow us to observe a student's development and engagement in the course without relying on traditional academic work such as assignments, quizzes, and exams. Such traditional academic tasks generally confine students to memorize and repeat what they think will allow them to pass the course. Furthermore, traditional problem sets, quizzes, and exams allow very little self-expression from the students. Students are afforded little to no space to communicate their personal thoughts with the faculty without significant effort on the part of the student or fear of retaliation. To overcome these barriers, an inquiry-based learning approach is taken [23], [24], [25], [26], [27]. This approach allows students to explore how they learn by providing a space to ask questions and build on their existing knowledge, further deepening their connections. Prabhu Gaunkar has adapted a model of inquiry for students with subdividing inquiry stages to identify which state the students are in. Briefly described, these states are:

1. **Identification** - Students are trying to figure out what the course is about and how their learning practices fit in.
2. **Reflection** - Students are in an early reflection stage where they think about their initial solution and try different things by making mistakes and learning.
3. **Personalization** - Students are in a phase of metacognitive reflection. They think more deeply about their solutions and beliefs, questioning their beliefs and enter a deeper cycle of inquiry. At this stage students are able to make connections and may emancipate from mimicking.

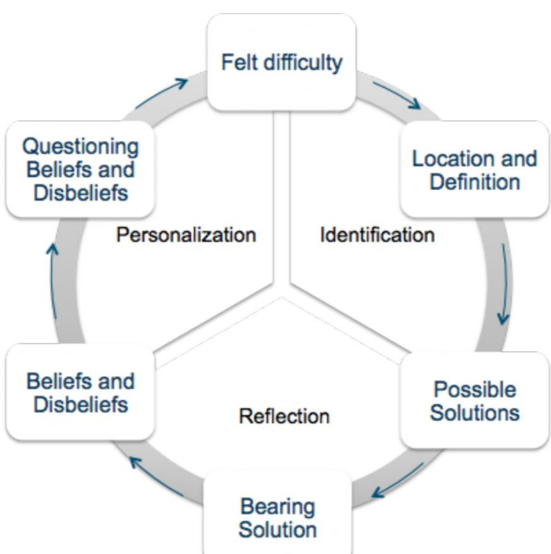


Figure 1: *Dewey's Cycle of Inquiry* [18]

The cycle of inquiry gives students permission and the space to be *self-aware* of their learning habits. We see this self-awareness as being transferable to the empathy cycle.

Empathy: Integration into Design and Engineering

Godfrey T. Barrett-Lennard, a renowned counselling psychologist specializing in therapeutic relationships, first described the empathy cycle in 1981 [28]. The expanded model [29] of the empathy cycle is comprised of four interconnected and often overlapping steps. They are as follows:

1. **Empathetic Attention** - Person A actively listens to Person B
2. **Empathetic Resonance** - Person A experiences a shared emotional state related to the topic of conversation with Person B
3. **Expressed Empathy** - Person A expresses their resonance from step 2 to Person B
4. **Received Empathy** - Person B confirms that Person A has indeed experienced the same emotional state and that they feel understood on an emotional level

Kouprie and Visser [3] proposed a framework for incorporating empathy into design. Similar to the empathy cycle, it also has four steps:

1. **Discovery** - the designer discovers and enters into the user's world
2. **Immersion** - the designer is pulled into the user's world and explores, absorbs, and experiences without judgement
3. **Connection** - the designer uses their immersion experiences to form a bond with the user, understanding both emotions and meanings
4. **Detachment** - the designer steps back from the firsthand experiences and emotions in order to engage in meaningful ideation

In both Barrett-Lennard and Kouprie and Visser's models, self-awareness is a necessary part of the cycle. Self-awareness is needed to help Person A differentiate the self from Person B in order to give empathetic attention and receive empathy from Person B. Likewise, the designer must be self-aware when they enter into discovering their user's world and again when detaching in order to ideate. Kouprie and Visser's model focuses on how the designer can understand the user's world and emotions in order to design with meaning. In contrast, engineers often focus on technical aspects of design, disregarding the user's emotional response to the design.

Walther, Miller, and Sochacka recognized that a framework for integrating empathy in engineering was needed. They proposed a model which conceptualizes empathy as a skill, a practice orientation, and a professional way of being [30]. Their model purposefully intertwines Being, Orientation, and Skill as they are mutually dependent and supportive in nature.

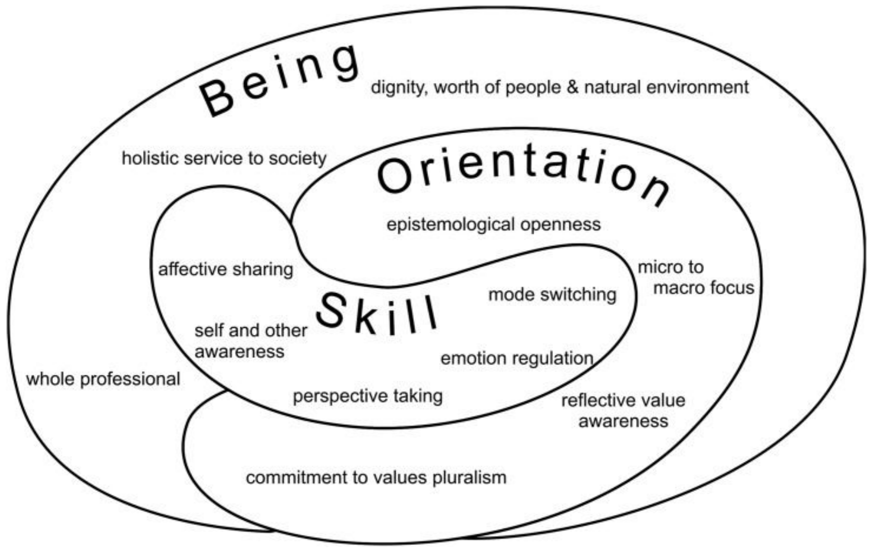


Figure 2: *A Model of empathy for engineering as proposed by Walther, Miller, and Sochacka.*

Empathy as a skill is rooted in research by Decety and Moriguchi [31], who define empathy as being comprised of four components: affective sharing, self and other awareness, perspective taking, and emotional regulation. The addition of mode switching by Walther, et. al. was deemed necessary specifically for engineers. Mode switching is defined as the "ability to recognize, consciously apply, or switch between empathic and analytic cognitive mechanisms." Both empathy and mode switching are classified as skills since they can be practiced and improved.

Method and Analysis

A qualitative approach is taken to compare and contrast the end-of-semester reflections from three courses taught by the same professor. Course A, Electromagnetism for Electrical Engineering, is an electromagnetics course that is required for electrical engineers. Course B, Electromagnetism for Non-Electrical Engineers, is focused on application, historical development, and practice. While Course B is open to all students, it is primarily taken by non-electrical disciplines of engineers. Course C, From Thoughts to Things, is a course for non-engineers that is focused on engineering literacy and how things work. Course C is required for industrial design students and is taken primarily by students in the College of Design. A summary of the key components of the courses is laid out in Table 1.

Table 1: *Course Summaries*

	Course A **EM or EEs**	**Course B** **EM for Non-EEs**	**Course C** **From Thoughts to Things**
Course Name	Electromagnetic Fields and Waves	Electromagnetics for Non-Electrical Engineers	Engineering: Getting from Thought to Thing
Student Demographic	Electrical Engineers	Non-Electrical Engineers, mostly engineers	Industrial Designers and other students in Design
Course Catalog Description	Fundamentals and applications of electric and magnetic fields and materials. Electrostatics and magnetostatics, potentials, capacitance and inductance, energy, force, torque. Uniform plane electromagnetic waves, Poynting vector. Transmission lines: transient and sinusoidal steady-state conditions, reflection coefficient.	Conceptual study of electromagnetism and its application in engineering and related fields. EM fundamentals, EM spectrum, radiation, radiating systems, wireless, modern concepts of physics, quantum computing, transmission lines, high speed effects, waveguides, GPS and other related phenomena will be discussed and explained with the application in mind.	What is engineering, technology and their roles in society? Investigation of engineering methods through case studies of everyday objects. Explore questions about the impact of technology in society. Apply engineering methods to design and failure analysis.
Course Prerequisites	● Electric Circuits ● Calculus III ● Introduction to Classical Physics II	● General Physics or Introduction to Classical Physics II	● None
Course Goals	● Mathematical and technical competency	● Conceptual understanding of electromagnetics and 20th Century developments	● Technological and engineering literacy ● Show the human side of engineering and how it relates to design
Methods of Evaluation	● Regularly Scheduled Tests ● Final Exam	● Final Project	● Final Project

All three courses are loosely based on the connected curriculum framework proposed by Jones and Mina [18] and incorporate the fundamental elements of definition, connection, and reflection. The focus of class time is shifted away from lecturing, instead following a pattern of reading, small group discussion and problem solving, large group discussion, and reflection. In-class work primarily consists of daily "games" instead of traditional quizzes which allows students to work together to reflect on the topic on hand. "Games" can include new terms, concept exploration, or problems to solve. Homework assignments are designed to stay away from traditional, lengthy, formulaic problem sets and instead focus on approaching problems from a different perspective, giving students the opportunity to connect the ideas that were discussed in class. Course activities such as class discussion, games, and homework purposefully connect and build on the previous topic to help students create a more integrated story of the course by offering more opportunities to reflect. The goal is not to "teach" but to *facilitate* students' learning through these methods. These courses strive to promote an inclusive environment in which the students know that the in-class work is for them to play, try various solutions, make mistakes, and learn. Students are encouraged to provide feedback throughout the semester so the course can be dynamically adjusted to meet the students' needs.

The student reflections were analyzed with NVivo, a qualitative data analysis (QDA) computer software program. Special attention was paid to overall themes and keywords associated with empathy, then narrowed down to 5 themes. The themes used are: Self-Awareness, How I Learn, Exploration, Appreciation, and Community. Each theme is associated with Goleman's five key elements of EQ:

Table 2: *Themes Used for Data Analysis*

Theme	Five Key Elements of EQ
Self-Awareness	*Self-Awareness* - ability to recognize and understand one's own emotions
How I Learn	*Self-Regulation* - ability to manage one's emotions and take responsibility for their own actions
Exploration	*Motivation* - either intrinsic or extrinsic; the desire that drives goal-oriented behaviors
Appreciation	*Empathy* - ability to understand how others feel
Community	*Adeptness in Relationships (social skills)* - ability to connect well with others

In order to code these themes within students' reflections, we chose keywords that reflected empathy in the context of the self and other. These keywords are: connect, experience, feel, learned, and understand. The themes were first manually coded and then autocoded. Manually coding allows us to have a reference for the autocode function in NVivo. In our results, we acknowledge that the percentages are in regards to the number of coded paragraphs in each course file and is not a proportional analysis across all three courses. The analysis allows us to get a general sense of the different groups of students and how they compare with each other.

Results

At a high level, the reflections gathered from the students in Course A, EM for EEs, indicate that the students are self-aware of their learning habits and wish to do better. Their responses are factual and only relate to their engineering program. In Course B, EM for non-EEs, students show self-awareness of the methods that help them learn the best. Students from Course B often wanted to explore more of what they learned or hadn't learned in the course on their own. They valued the community that discussions and games fostered. In Course C, From Thoughts to Things, students generally showed self-awareness and empathy, often talking about working with others and a sense of community. Reflections were thoughtful, introspective, and honest, citing that they learned a lot about themselves as designers. A large number of students from all three courses favored the way the course was taught and claimed that it had been unlike any other course they had taken. Other frequently mentioned, positive aspects of all three courses were that students enjoyed the in-class demonstrations, the concrete connections to real-world applications, and the low pressure learning environment. One notable difference between the reflections of the three courses is that Course A, EM for EEs, did not mention feeling a sense of community, while both Course B and Course C did. When asked what the teaching faculty could do to help the students learn more, many students responded that the teaching faculty was not at fault, but they, themselves could have done things differently to improve their learning. This type of self-awareness was a major theme amongst both engineers and non-engineers.

The following figures show the percentage of coverage in coding for each course regarding our themes of Self-Awareness, How I Learn, Exploration, Appreciation, and Community.

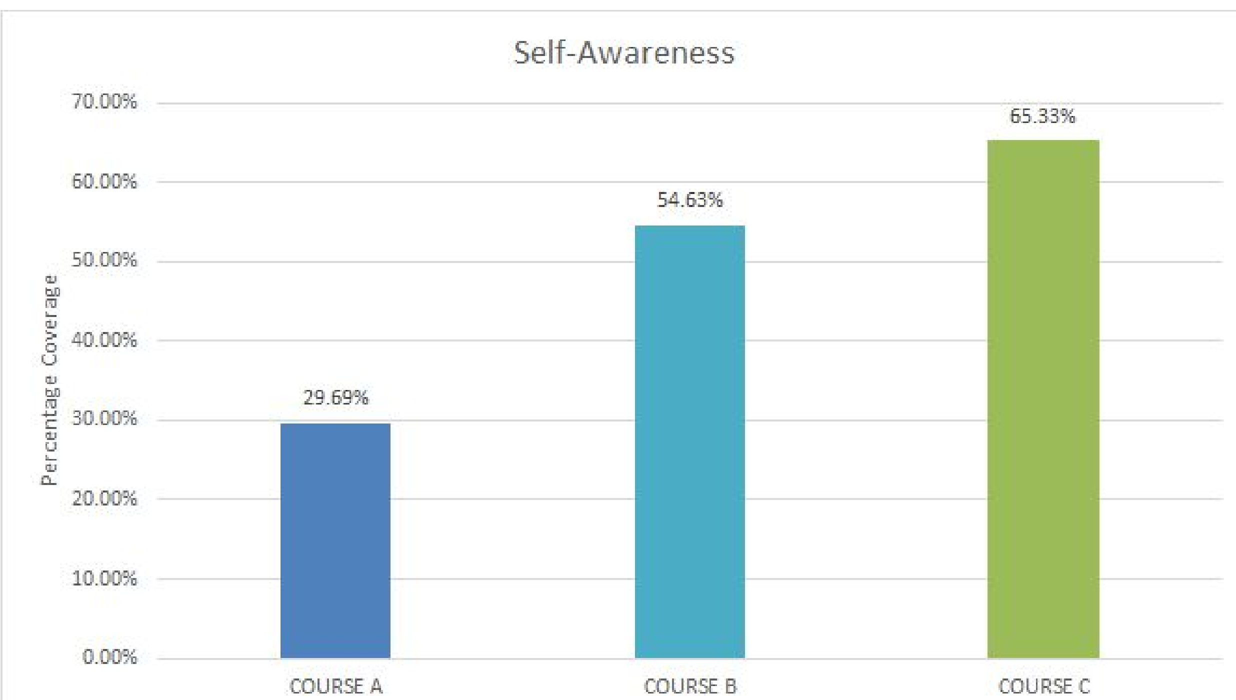


Figure 3. *Self-Awareness. Reviewing the codes for self-awareness, many of the students' reflections acknowledged their emotional response in the course, using phrases such as "I feel", "I understand", "I think", and is usually followed with awareness of their learning habits and practices. While courses B and C showed a high amount of this theme, Course A showed a low amount of self-awareness.*

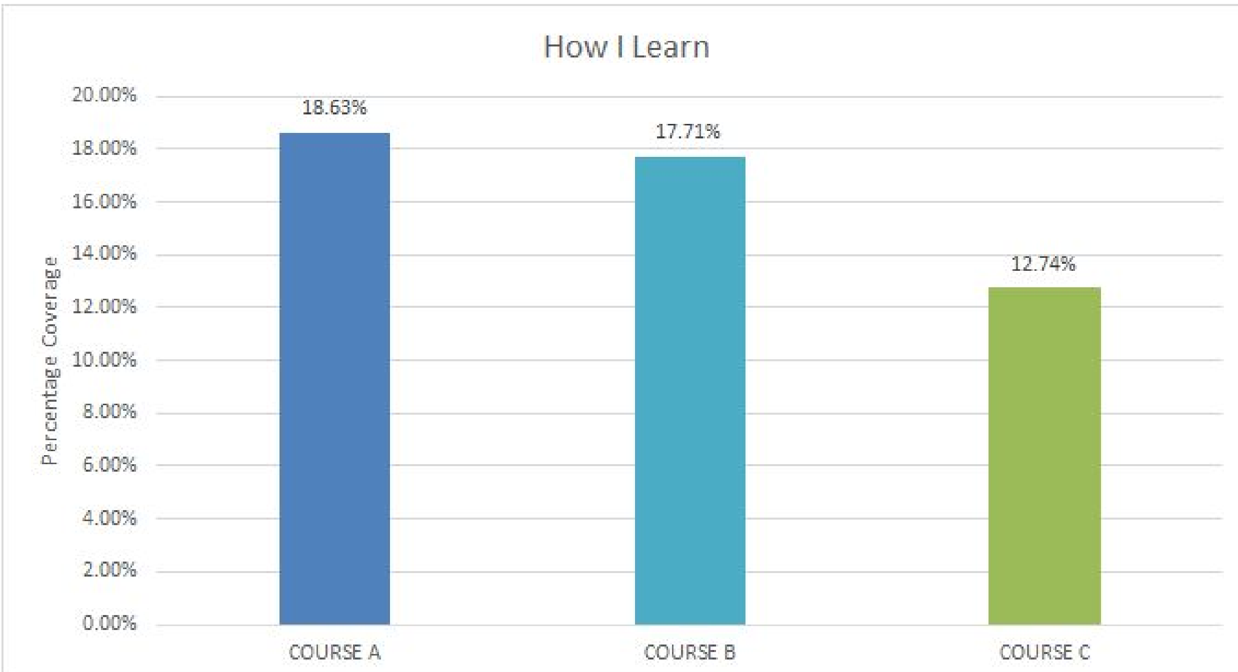


Figure 4. *How I Learn. Our team looked for phrases and keywords where students reflected on their learning habits, such as "I learn best", or "I learned that I". All three courses showed reflection of students' learning practices.*

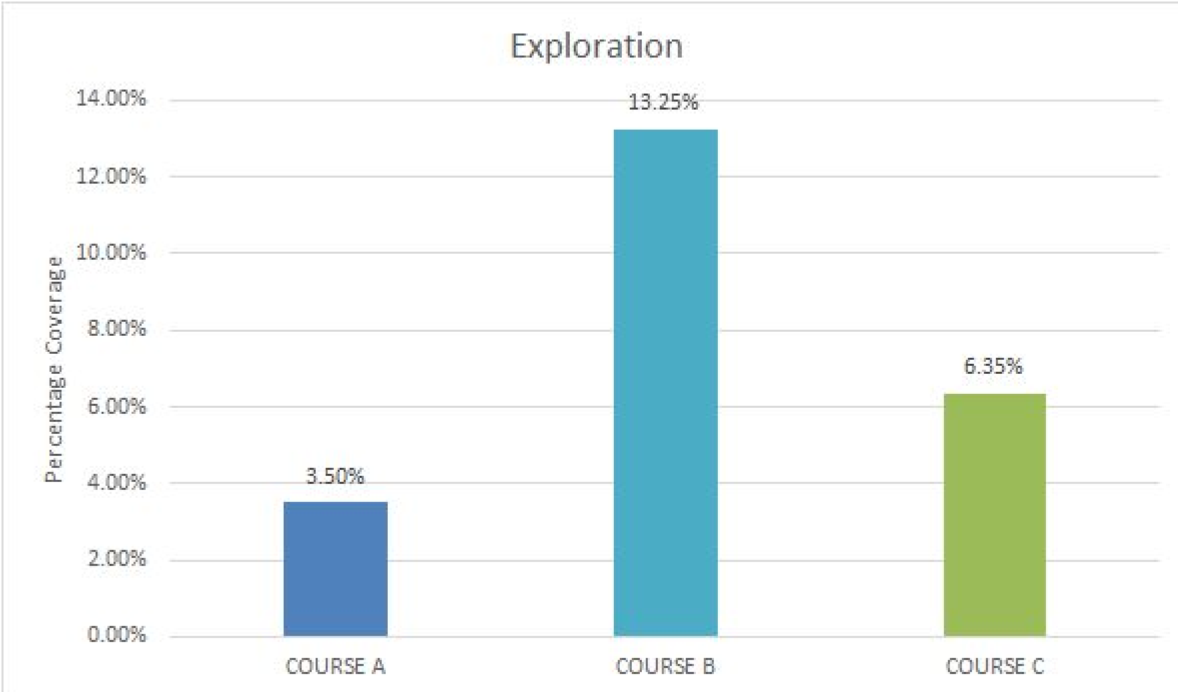


Figure 5. *Exploration. Our team looked at whether or not students are showing interest beyond what was discussed in the class period. Students in Course B and C showed more interest in learning beyond the class topics, while Course A showed very little exploration.*

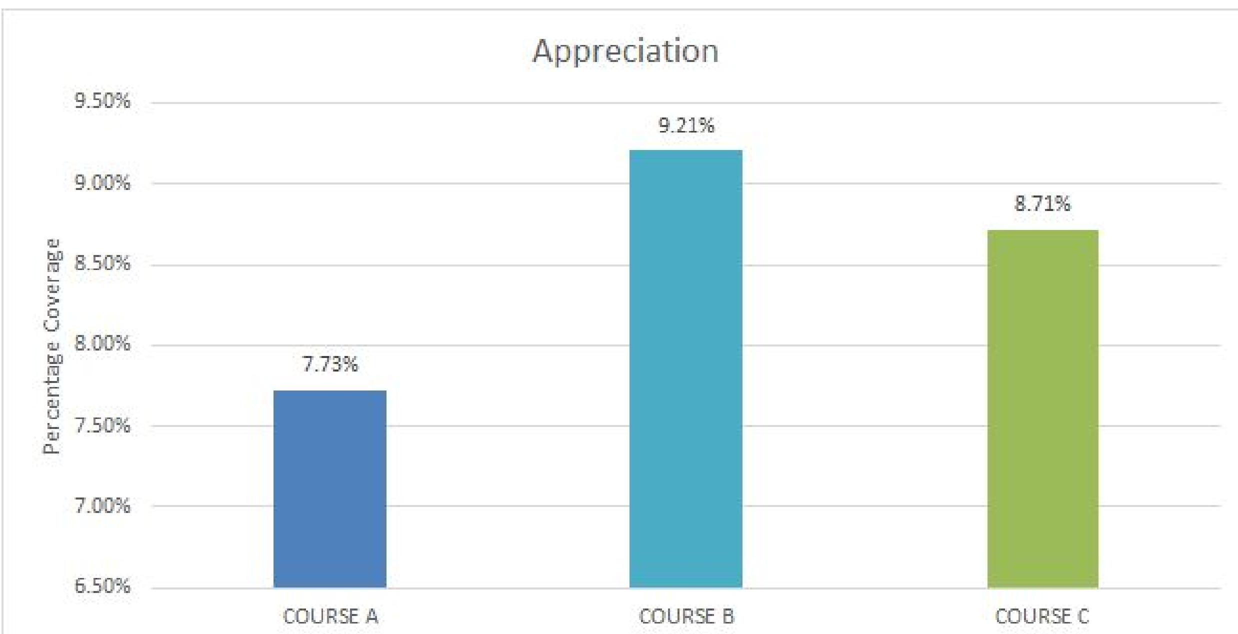


Figure 6. *Appreciation. We looked for students' ability to recognize and understand the professor and the professor's teaching practices. Reflections from all three courses show that students enjoyed the course, the professor's style of instruction, and acknowledged the professor to be relatable, caring, and not an "authority".*

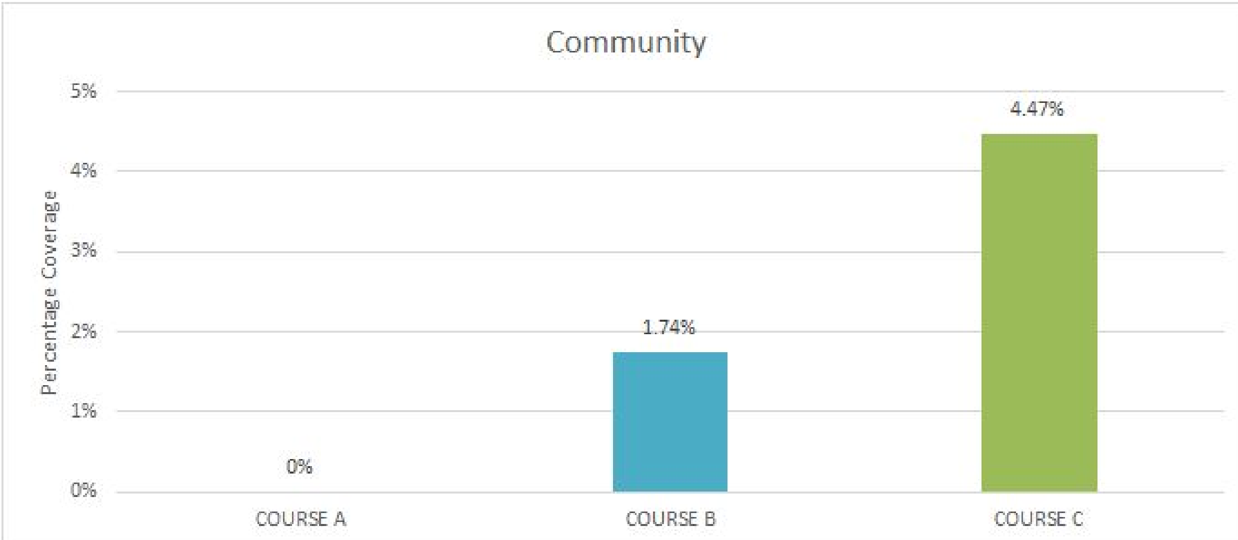


Figure 7. *Community. We looked at phrases that contain shared experiences between students, such as working in groups or having discussions. Reviewing the codes, our data shows that Course C highly valued community, Course B acknowledged the value of community, and Course A showed a lack of community.*

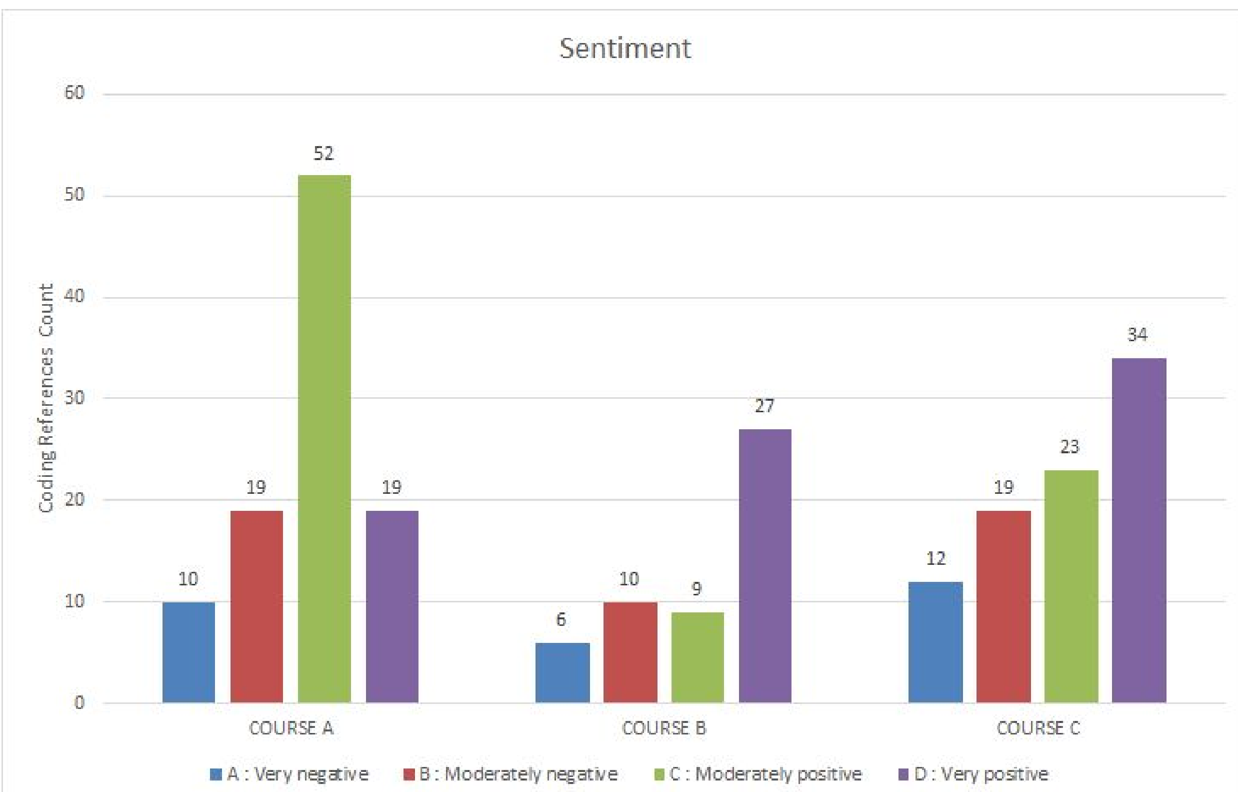


Figure 8. *Sentiment autocoded using QDA software categorized from very negative to very positive.*

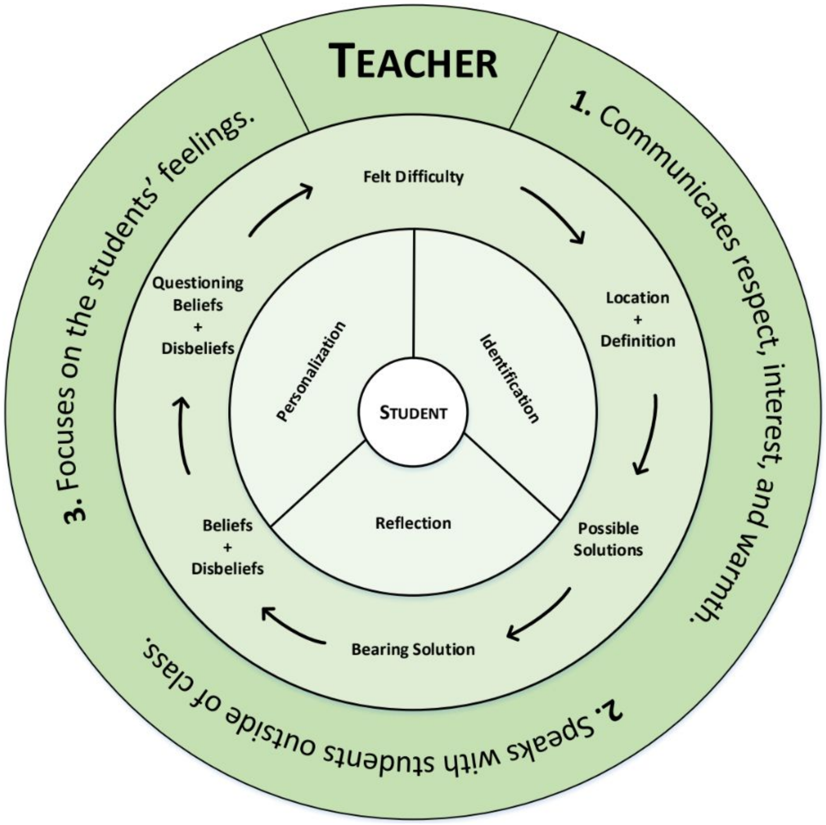
To get a sense of feeling from the student reflections in each course, the autocode feature for sentiment was used (as seen in Figure F.), which scans for content that expresses emotion, categorised from very negative to very positive. As mentioned at the beginning of this section, students from all three sections mentioned that the course was unlike any other course they have taken and generally found the course favorable.

Proposed Model

The model we propose is a multi-cycle model that takes elements from the cycle of inquiry, the empathy cycle, empathy in design, and empathy in engineering. The student is placed at the center of the cycle of inquiry while the teacher encompasses the cycle to represent facilitation of learning with an interpersonal focus. Self-awareness is a product of this cycle to which we believe is transferable to an empathy cycle. We call this cycle *A Cycle of Inquiry Through A Student-Centered Approach.*

The need for empathy, design thinking, and engineering is integrated into another cycle we call *Empathy in Design for Engineers*. We use the addition of mode switching, the ability to move from empathy to analytical states, as described by Walther, et al. There are two states, State 1: Self-Centered, and State 2: User-Centered, which the engineer can easily differentiate. State 1 implies that understanding the self from others is critical before reaching State 2, which is focused on the user. Once the engineer is able to differentiate the self from others, they are then capable of addressing the needs of the user, through Listening, Resonance, Connection, and Detachment.

A Cycle of Inquiry Through A Student-Centered Approach



SELF-AWARENESS

⬇

Empathy in Design for Engineers

State 1: Self-Centered
0. **Self-Awareness** - understanding of the self
1. **Other Awareness** - differentiating the self from others
State 2: User-Centered
2. **Listening** - engineer is pulled into client's world, exploring, absorbing, and experiences without judgement.
3. **Resonance** - engineer shares emotional state with client related to client's needs
4. **Connection** - engineer uses shared resonance to form a bond with the client, understanding emotions and needs
5. **Detachment** - engineer steps back from interaction with client and switches modes from empathy to analytic to design for client's needs

Discussion and Conclusions

Understanding what we know about the three different groups of students, we expected to see industrial design students to have higher amounts of empathy, including self-awareness, than engineering students in general as industrial design already has empathy tightly intertwined within their curriculum. What we can generalize about the data above is that engineering students value classes which allow them to form communities; such as teams and group discussions, the ability to explore topics of interests including their learning habits through inquiry and reflection, and are appreciative of a professor who shows care for their students in the way they learn and in an emotional capacity. Electrical engineering students in particular showed little empathy in their reflections, but showed self-awareness of their learning habits and how they could do better. This self-awareness we believe is transferable as shown in our proposed model.

Future Work

Future works from our team will investigate the impact empathy has on student retention, student community, and discipline reputation. The ultimate goal of this series of explorations into empathy is to examine and provide a framework for how empathy can be identified and included in the pedagogical approach of the educators, in particular for engineering programs that remain mostly focused on traditional curriculum and teaching methods. We believe that increasing empathy in the classroom can lead to an increase in diversity among engineering students, in turn leading to engineers more capable of producing robust and creative solutions.

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