Impact of Human Side of Engineering Approach in an Undergraduate Electromagnetics Course

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In most electrical engineering programs, the undergraduate electromagnetics course is required for all students. Broadly, the course delves into historical perspectives, vector calculus-based problem solving and concepts of wave propagation. Several students consider the course to be challenging since they are required to connect electrical engineering concepts through the platform of vector calculus. To address this challenge, in our course, students participate in a set of in-class activities (reflections) where they discuss, review, and think about the concepts and their learning, and then solve related problems in small groups. Each student brings a unique perspective in terms of what they might already know or have figured out while listening to the instructor. The groups work together to solve the problems and submit their work (reflections) at the end of the activity. Our approach provides students with an opportunity to interact with one another, learn from different perspectives, work through the problems and also reach out to the instructor with possible questions. It is expected that while the concepts are still challenging, the students can find ways of working through them by solving problems in class with the support of their peers. This method, where students share their learning process in-class and learn together is the main approach towards creating a community-based inquiry environment where the humans can engage not as viewers but as active participants and thinkers. In our work, we will study the in-class activities to quantify the impact of the learning environment on the students learning. Ultimately, we will seek to see if the students benefit from learning as a community.

***Keywords*—Inquiry, Human side of Engineering, Reflection, Electromagnetics**

I. INTRODUCTION

UNDERGRADUATE electromagnetics courses are foundational to the electrical engineering curricula. Students typically take this course in their junior or senior years after they have completed courses related to vector calculus. The junior year course involves a calculus-based approach towards representation of electrostatic and magnetostatic fields and boundary conditions. In addition the class also provides an overview of wave propagation in free space/other media and in transmission lines. Some variations may also include an introduction to devices such as antennas or waveguides. Each aspect of the course requires students to use vector calculus. Thus, the students start the course by reviewing fundamentals of calculus and then begin applying it to concepts from electrostatics, magnetostatics etc. While the calculus-based approach is used to help students understand basic concepts with ease, it is observed that in the initial phase of the course students seem to struggle to make connections between the mathematical concepts and the electrical engineering aspects [1 - 4]. However, once the students can make this connection, we observe that they have an easier time trying to understand the concepts. In order to target the connection gap, the students experience, we have worked at developing an adaptive inquiry-based approach for our classrooms. This approach, initiated by John Dewey [6,7] has been adapted to include the presence of an in-class community. Traditionally, as seen in Fig. 1, the inquiry-based approach as proposed by Dewey involves five stages. The student starts with a) A felt difficulty then proceeds to b) location and definition, followed by finding c) possible solutions & d) bearing the solution. The final stages involve e) forming beliefs and disbeliefs and f) questioning formed beliefs/disbeliefs leading to a re-entry into the inquiry cycle. While this model is applicable to each individual, the time period that each person takes to go through the cycle would vary. This would be a definite deterrent in a fast-paced course such as an undergraduate electromagnetics course.

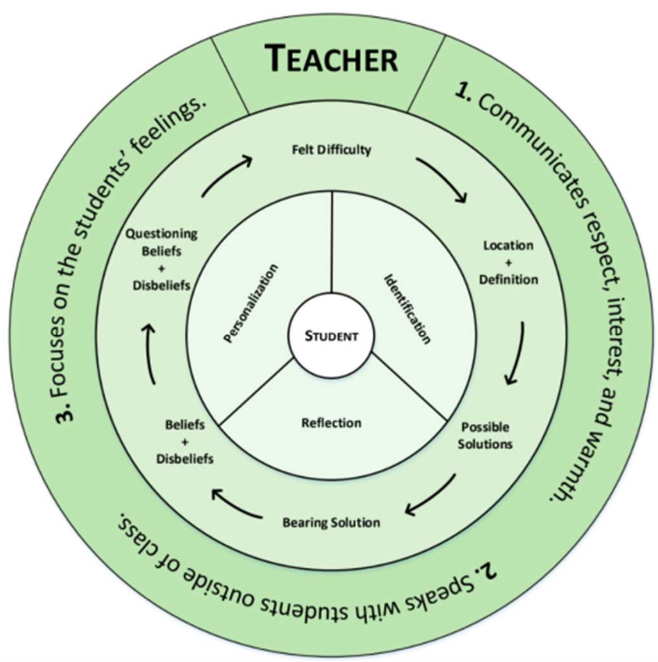

Fig. 1: Representation of a cycle of inquiry through a student-centered approach [5]

In our inquiry-based electromagnetics course [8], we seek to assist students in their learning process by allowing them to interact, share, and debate while they work through the different in-class problems or reflections. By interacting with one another and sharing their thoughts, at times it is possible to just copy and follow along something that the group's leader suggests.

However, since each student has to submit individual work, it is possible to understand their attempt to connect their ideas to what they have learned and what the team suggests. This process of sharing ideas while learning in the classroom also provides the instructor with a chance to intervene if a concept is not well understood. It is our observation that such a technique can prevent any major conceptual confusions.

Our adaptive inquiry-based instruction approach involves intervention through community interactions [8 - 10]. We consider this to be a human sided approach for our undergraduate electromagnetics course [11]. Our hope is that by forming connections with their peers, the students are able to evolve their thought processes faster and can retain concepts beyond memorized equations. In this paper, we will examine reflective activities from students to evaluate the effectiveness of in-class interactions on students' work.

II. RESEARCH FRAMEWORK

Our assessments are based on a content-analysis technique of the in-class reflective activities [12,13]. In our course, daily reflection activities or games are conducted in each class. The purpose of these activities is two-fold. First, the students must commit to their learning from that lecture by the end of the class. Second, they have an opportunity to interact with their peers and seek clarification for any concepts they haven't understood during the lecture part or reading the material of the class. The students also know that the reflection is not a quiz, it is a measure for their personal learning. So, the activities, that are called games, are to help facilitate students work/thinking/experimenting, and learning. These are low-stake activities and making mistakes is not going to affect the students' final grades.

The class is set up so that the students know the real purpose is learning. Initially, some students are concerned about the grade and aren't willing to share their views in the games. However, over time they can adapt to the interactive nature of the reflective activities. For this paper, we have selected a few reflective questions for qualitative assessment. Common trends or patterns are identified from the reflections. Our assessment will show the inquiry-stage the student may be present in. If the students are found to be in the stages of reflection or personalization as per Fig. 1, it would imply that they have benefited from the interactive nature of the classroom.

III. ANALYSIS OF REFLECTIONS

An example of a few in-class reflection problems which were used in our assessment are shown below. The initial problem was selected from approximately the 4^{th} or 5^{th} week of the semester. The next problem was selected from approximately the 8^{th} to 10^{th} week of the semester.

Problem 1: In cylindrical coordinate system, you are given the following vector at a point in space.

$$\vec{A} = 2\hat{x} - 2\hat{y} - \rho\hat{z}$$

a) Find the divergence of $\vec{A}$.
b) How much of this vector is along r?
c) Do the following integral $\int_{-3\pi}^{8\pi} \vec{A} d\emptyset$ and show your detailed work.

Problem 2: You are given the following charge distribution

$$\begin{array}{ll} A.\rho & 0< \rho < b, \text{C/m}^3 \\ 0 & \text{b}< \rho < c \\ K & \rho = b, \text{C/m}^2 \\ 0 & \rho > c \end{array}$$

a) Find electric flux density for all points in space.
b) Examine the electric boundary conditions at $\rho = b$ and $\rho = c$.
c) Find divergence of electric flux density in the region.

For these problems, the instructor introduces the basic concepts in class, goes through a few examples and the students then work alongside their peers to obtain a solution. These activities are done in each lecture. The problems used here are representative of the weekly in-class reflections the students work on. The problems are typically numerical and require the students to work through multiple steps to reach a solution. At each step the students can work with their peers to discuss their learnings and ask the instructor for clarifications. The goal of these assessments is primarily for the students to identify what they have learned and understand what they might have missed while the instructor was teaching. The in-class activities give them a chance to directly apply what they understood and further build on that knowledge with peer interactions. Eventually, they also work on similar problems for their assignments. An additional benefit of such daily activities is that the instructor can also understand where the students are struggling and can reiterate on certain concepts if necessary. It is expected that over time, the students can accumulate a certain level of understanding and can step through the different stages of inquiry as shown in Fig. 1. For our assessment, we assess the stage of inquiry the students are at by seeing if they can set up the problem, identify the correct approach to solving the problem and use their learning in working out a solution. The final solution need not be accurate, our goal is to ensure that they follow the logical steps in approaching the problems and have understood the concepts. Since every student takes a certain amount of time to thoroughly understand concepts, we expect them to be at different stages of the inquiry cycle while they solve the reflection activities. We have measured this gradation in learning stages for 22 students in an undergraduate electromagnetics course. This assessment was performed on data collected during an in-person course. All the reflective activities and peer interactions occurred in a classroom environment. The students typically spent 20 minutes in each class for the reflection activities. The rest of the lecture was used by the instructor to introduce the concepts and the examples.

The students' responses for each were classified into the different stages of Deweyan inquiry as shown in Fig. 1. The problems were designed such that the students who had basic understanding could be in the initial stage of inquiry or identification (stage 1) and would be able to attempt at least part a of each problem, the students who were able to understand a bit more could be in the stage of reflection (stage 2) and find a solution to part b and the students who were able to solve part c were typically in the personalization stage (stage 3). However, in some cases students could attempt at least each part partially and they were then classified into the identification stage. A comparison was made to identify if the students could progress through the different inquiry stages with the progression of the semester.

For Problem 1, as seen in Fig. 2, for Part 1a and Part 1b, more than 60% of the students are in the reflection or personalization stages, while for Part 1c approximately half of the students were in the initial learning stage and were unable to identify how they could approach the problem. For the students who were already in stage 3 i.e., personalization, they were also able to solve the problem in more than one way and were able to verify their solutions before submission.

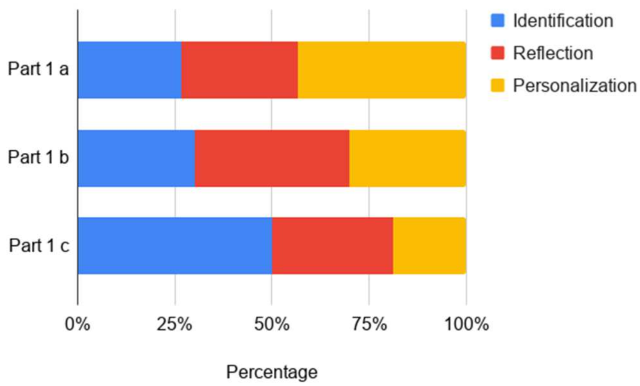

Fig 2: Results obtained after qualitative analysis of students' reflections for Problem 1

For Problem 2, the reflective activity was selected towards the end of the semester. This implies that the students had formed a fundamental background and were now in a deeper problem-solving phase. The expectation was that the students would be able to solve all three parts of the problem and maybe a majority of the class would be in stages 2 or 3 of inquiry. The analysis result in Fig. 3 shows us that for Problem 2, Part 2a and Part 2b approximately 50% of the students could reach the higher stages of inquiry. However, many were still in stage 1 since they had difficulty with the vector calculus set up. In problem 2, Part 2c, we see that approximately 75% of the students could reach the higher stages. This implies that they were able to setup the problem, understand the requirements and proceed to solve the required boundary conditions or equations. The students in stage 2 (reflection) potentially had some minor mistakes in the setup and were not able to obtain the required result. However, they had a good grasp of the concepts and requirements.

Overall, between the first and second analysis, we observed that the students were able to make progress from the identification stage to reflection or personalization as the semester progressed. These observations shown that with regular in-class reflection activities and peer interactions, the students were indeed able to solidify their learnings and they were able to implement their knowledge to solve different types of problems that required a good understanding of vector calculus and electromagnetics.

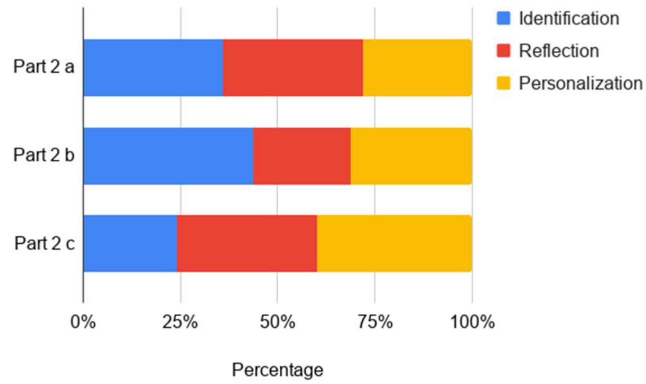

Fig 3: Results obtained after qualitative analysis of students' reflections for Problem 2

IV. CONCLUSIONS

In this work, we have examined the impact of using an adaptive inquiry-based approach in an undergraduate electromagnetics course. We have observed that once the students begin to engage with their peers, their reflective activities show improvements, and they demonstrate advancements in their learning. These advancements were qualitatively assessed using student's in-class reflections and categorized as per the stages of growth in the Deweyan inquiry cycle. This work shows that inclusion of a human-sided inquiry approach in engineering classrooms can help students find a way to connect not only with their peers but also with the course content.

V. FUTURE WORK

In this work we assessed the impact of incorporating a human-sided approach in an inquiry-based classroom. For our next study, we will seek to understand which aspects contribute more to the student's growth within the inquiry process. We will evaluate if the students can move faster if they receive more feedback from the instruction team or with more interactions with their peers. While this assessment is limited to an undergraduate electromagnetics course, the results show that with regular in-class activities and peer interaction, students can retain concepts and be engaged in their learning. We seek to understand if this learning paradigm is transferrable to other engineering courses within our department.

VI. ACKNOWLEDGEMENTS

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