Revisiting classroom environment and activities: Reexamination of mistakes and learning cycles

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Abstract – This paper addresses some of the difficulties we see in many engineering classes. A majority of engineering classes are still taught using the conventional lecturing system whereby the professor talks in front of an audience, be it in person, online, pre-recorded, or a hybrid system. In today's information technology age, students naturally turn to online lectures and YouTube videos for topic-specific notes or practice to get ready for the exams. Many of the incoming college or university students spent their high school years in social isolation or lockdown due to the COVID-19 pandemic. The concept of teams and collaborations has not been the main mode of their learning and engagement in classes. This situation can have an adverse effect on their development when they join an institution of higher learning. There is considerable research conducted on the advantages of integrating elements of teamwork, collaboration, and experimentation with the team for in-class activities. This approach is shown to be especially effective for some of the early classes. In this work, we would like to focus on our experience in using in-class engagement and collaborating activities as the main mode of our classes in Introduction to Electrical Engineering and the undergraduate-level Electromagnetism. This process is a modified version of existing active learning practices. The main idea is to engage students with continued in-class activities and team-based work that encourages students to examine and learn together. Students will work together to tackle problems that would emphasize the basic and the main ideas, methods, and thought process that we would like the students to engage with and develop conceptual comfort and mastery over time.

The paper will introduce the idea and process that we have reported in earlier papers after working with undergraduate students over the years. Next, we will introduce and discuss the two classes (Freshman Engineering and Electromagnetism) where we deployed the method. We will also highlight the students' work and introduce their journeys by sharing their reflections and some examples of their activities and challenges. The main question that we are trying to ask and find evidence for is, "Can we re-engineer mistakes and use them as an important part of the learning, changing, and adapting to the process, examinations, and growth of the students?" We found that providing low-stakes learning opportunities is impactful in encouraging collaborations among the students and allowing them to openly engage in their own identity, discuss, examine their knowledge and not be afraid of mistakes. In addition, students are more willing to learn from their mistakes, which we argue is the more meaningful approach to achieving effective learning because they are experiencing a better path and interactions for facilitating their experience that would result in remembering the learning and the process.

I. Introduction

The role of educators is to facilitate the students' journey. Educators create safe space for students to learn, make mistakes, emancipate, and create an identity for themselves [1].

Educators rely on conventional tools such as lectures, class activities, assignments, quizzes, and exams to educate their students. Over time, more research has gone into other effective learning tools. Research records successes from learning by doing, learning from mistakes, team-based learning, and problem-based learning [2][3][4][5]. We have experimented on in-class engagement and collaborating activities as the main mode of our classes in Introduction to Electrical Engineering (Introduction) and the undergraduate-level Electromagnetism (EM). On an average semester, these classes have 120 and 75 students respectively. Due to the size of the classes, the Introduction class has five undergraduate peer mentors as part of the instruction team while the EM class is conducted by the instructor and a graduate-level teaching assistant. The main instructor is responsible for keeping track of the students' development while the student helpers provide additional feedback and perspectives to aid in better understanding the students. We also brought in elements of learning from mistakes. The model we have created has seen great success as we reported in previous works [6].

However, the COVID-19 pandemic had caused a ripple effect in the education scene. Educators are encountering new problems with many learning models especially collaborative-based. Our recent experience and research in engineering education show promising results from our model post-COVID. Our approach to encourage students to work together on problems and to learn from their mistakes can and will allow them to have a more connected and emancipated learning experience. the doors for more emancipated learners. A close evaluation of our model shows that this methodology creates a positive, team-friendly, and constructive environment for the students to learn, make mistakes, relearn, and advance their overall competence. The students also create meaningful connections between the theoretical and practical aspects of their learning [7][8].

II. Post-COVID challenges

During the COVID-19 isolation period, many places of education shut their campus down in favor of remote learning. As a result, many current college students spent their high school and freshman years at home, learning from a computer screen, and devoid of any social interactions. Now that we entered the post-COVID era, we observed the effects of these learning circumstances and how do they affect the students' development. This section serves to share the post-COVID challenges we observed among our students.

A. Social and communication aspects

The first major challenge we noticed is the impairment of the students' ability to connect with their peers. The current generation of students are socially awkward loners [9]. They do not know how to make meaningful connections or form a community [10]. Many of the students gravitate towards sitting in individual islands in the classrooms. Students tend to keep to themselves during class with little verbal interaction with the instructor. When asked to work in teams, students would sit together but worked on individual computers without acknowledging their teammates. Students also have little to no interaction with one another outside of the classroom. This is a concerning trend considering engineering students are consistently ranked

among the lowest in terms of social interaction pre-COVID [11]. During quarantine, they spent most days alone while watching lectures videos. They continue to do so even while surrounded by peers and a live instructor as we transitioned back to in person learning.

Students also struggled with other forms of communication. We noticed a significant increase in disorganized submissions, inappropriate emails, messy handwriting, incoherent reports, plagiarized work, etc. Based on their reflections and discussions with the instruction team, students have spent the last few years believing that short answers are enough to turn in. This manifests into weak presentations of their work processes, and overall poor communication skills for college level learning. This is the new norm for them.

B. Knowledge and understanding aspects

This is not a new problem. Most educators had encountered students with poor foundational and fundamental understanding of prior courses. This is the same for both of our classes, but the numbers have grown since the pandemic. In our freshman class, we see students who cannot comprehend high school algebra or trigonometry. In our EM class, students do not have much recollection of the basic circuits, physics, and calculus classes they took.

From our conversation with the students and through their reflections, one common theme brought up was the harsh high school and freshman experience they had. The students felt overworked and were constantly under pressure to keep up with the class. This is understandable. The collaborative environment does not translate well for remote learning. Educators barely meet with the students and rely on assignments to keep students on track. As a result, the students felt stranded but were constantly hammered with a heavy load and were pushed hard. Under pressure, students fixated by their grades took the easiest path forward which is to mimic solutions and examples from the most accessible source, the Internet. Students stopped thinking for themselves and become dependent on the Internet and YouTube videos to solve problems. Students bring in their dependency on the internet and YouTube videos during open-book, open-note activities in class. More students are claiming that they learn better from watching YouTube videos than from attending lectures. This halts their critical thinking process, and it shows when students blindly copy examples that do not fit the context of the given problem. It is not easy to balance completing the syllabus and caring for the students' wellbeing and development in life.

The educators also have their set of struggles with online classes [12]. They were unable to spend as much time and energy on the students who are hidden behind black screens with muted microphones. This disconnection worsens when the educators have to passively gauge the students' progress based on their submitted work. Since the students are ineffective communicators, the picture painted is inaccurate and tends to leave the unique students to fend for themselves. The educators also had to reinvent and adapt their methods to the constantly changing situation as new technologies were swiftly adopted. These factors left little room for the educators to polish their delivery method, a process that took years to accomplish.

C. Negative headspace and psychological pressure from society

The students considered themselves the 'unlucky' group. They accepted their fate as victims of circumstances, and they want to get through this hardship with the least amount challenges and of interpersonal interaction. College becomes a place of survival. This victim mentality is further amplified by how society treats them. They are constantly under the impression that society does not harbor hope in their capabilities. As a result, these students accept defeat before trying and are less motivated to change or stand up for themselves. They are willing to accept a passing grade and it shows by the lack of effort even when the instructor tries to reach out. They can be perceived as undisciplined, but we need to be able to empathize with them to be able to facilitate their learning and transformation.

III. Methodology and class structure

Students are conditioned to fear making mistakes. They are rewarded with better grades for making less mistakes. They hang on to the misconception that higher grades equate to better job prospect. Many students are stuck in the mimicry stage of learning because it allows them to be in the ballpark of the 'correct' answer with the least effort. Instead of thinking about the question, they spend more time trying to find the answer to the question. This method of learning will implode on themselves when they encounter a problem that they cannot mimic. We have observed more students who wrote "I do not know this question hence I cannot do anything about it" in their assignments. This is a nonconstructive 'fixed-mindset' for learning. Instead, we want to retrain our students to be curious and open-minded. We want our students to ask, "This is what I DO know about the question so how can I work through it?" instead. It is imperative that our students recognize what they do not know and still boldly attempt the question without a fear of making mistakes. They can learn more from their mistakes, so we should celebrate it [6].

A philosophical cornerstone of our approach in facilitating the students' learning is the Deweyan Cycle of as shown in Figure 1 [1]. This Cycle shows the stages a student goes through to achieve mastery over new materials. The students first identify what is missing in their understanding (felt difficulty) and potential solutions. The students then reflect on the solutions and test if the solutions stay true from different perspectives. Finally, the students revisit and examine their thinking and make them uniquely their own which enhances their long-term understanding. Instead of relaying the information directly to the students, we encourage them to form the ideation themselves. For this model to work, it is important to create a class environment that encourages exploration, bravery, and reflection on one's felt difficulty. An effective method is to use low stake activities. We call them games.

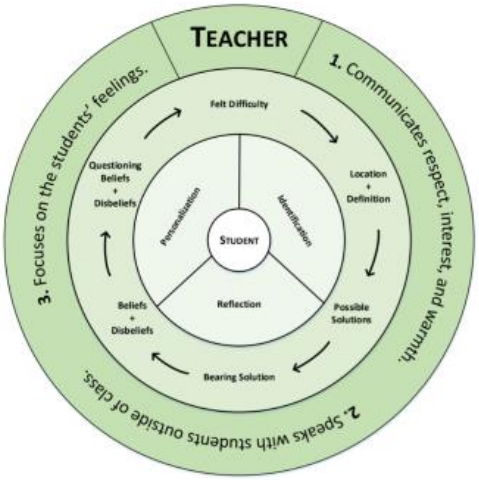

Figure 1. Deweyan Cycle of Inquiry through a student-centered approach: Students' challenges in learning and the instructor's roles in creating a safe space.

Games are quick ten to twenty minutes in-class activities. Students work in teams, but each member presents their work in their own language. The games include a diverse type of questions with elements of conceptual, divergent, rhetorical, and reflection. Questions are designed to be open-ended and challenge the students' on-the-spot thinking and understanding of the material. We want students to discover and identify their felt difficulty and initiate their engagement in the Cycle of Inquiry. This prompts students to dig into their knowledge well to identify possible solutions. They will then discuss with team members to test the validity and relevance of their thought process. The time limit is set to deter reliance on mimicry, but we are flexible with it whenever the class is struggling meaningfully.

Another pillar of our approach is the modified Kolbian Cycles of Learning [14]. This modified Cycle stresses the importance of reflection and an empathetic approach to see the students firstly as a thinking and engaging learner. As the students actively engaged in the games, we want them to proactively look back and reflect on their performance. The previous games should not be treated as done and forgotten. The previous games showcase the students' history in learning. Each game is a building block for the next game. Hence, the students' collective performance determines the next set of games. The games provide an opportunity to review, learn, and improve their work. We want students to hang onto their experience from each game and we recommend implementing a portfolio at the end of the semester for this purpose.

We always start the semester with explaining and reviewing both Cycles to give the students an expectation of what to come. Figure 2 illustrates how the games are created and applied for each class session. (Figure 2.1) We start the class session with a review of the previous games, solutions, and highlight the instruction team's observations. The review is important for students to recollect their thoughts on the prior materials and build upon it. (Figure 2.2) This is followed by a brief introduction to the topic of the day and a few conceptual examples. Finally, the game of the day is released as seen in Figure 2.3. During the games, the instruction team goes around to facilitate the teams' questions and discussions. The instruction team also interact with the students and build meaningful, empathetic relationships with them and among the team

members. Students who are not used to social interaction feel more connected to the instruction team and are more willing to reach out and speak their mind. We want to instill a sense of belonging and challenge their thinking that they are 'damaged'. The interactions also allow the instruction team to assess their depth of thinking and facilitate the discussion to focus constructively on the given problems. The instruction team brings the class back to clarify any misconception with a short discussion and explanation. The instruction team may move students around depending on the synergy of their team. The class session ends with a quick recap of where we are in the syllabus, reading assignments, and encourages them to review the game solution, keep on being engaged, and not to be disappointed with one or two low score games.

While grading the games, less emphasis is placed on the accuracy of the answers as seen in Figure 2.4. Instead, more attention is paid towards their thought process, logical connections, and conceptual understanding. Students are rewarded with extra credits based on their effort. Students are frequently reminded that the class will complete up to 70+ games in a semester, so they are not worth much individually. We find this assurance effective in getting the students to embrace mistakes as an important pathway to their learning and not fear the repercussion. Students are more likely to enter the next investigative stage of the Cycle of Inquiry as they grow more comfortable with owning up to their mistakes.

We are now in the new game generation process as shown in Figure 2.5. The instruction team scans the submitted games for signs of metacognition, articulation, connection, and reflection. These are signs of growth and learning progress that we are looking for. As shown in Figure 2.6, this progress is then translated into the new game. Each game is tweaked to address the previous misconception or dive deeper into interesting arguments or tie in to the next phrase of the class material.

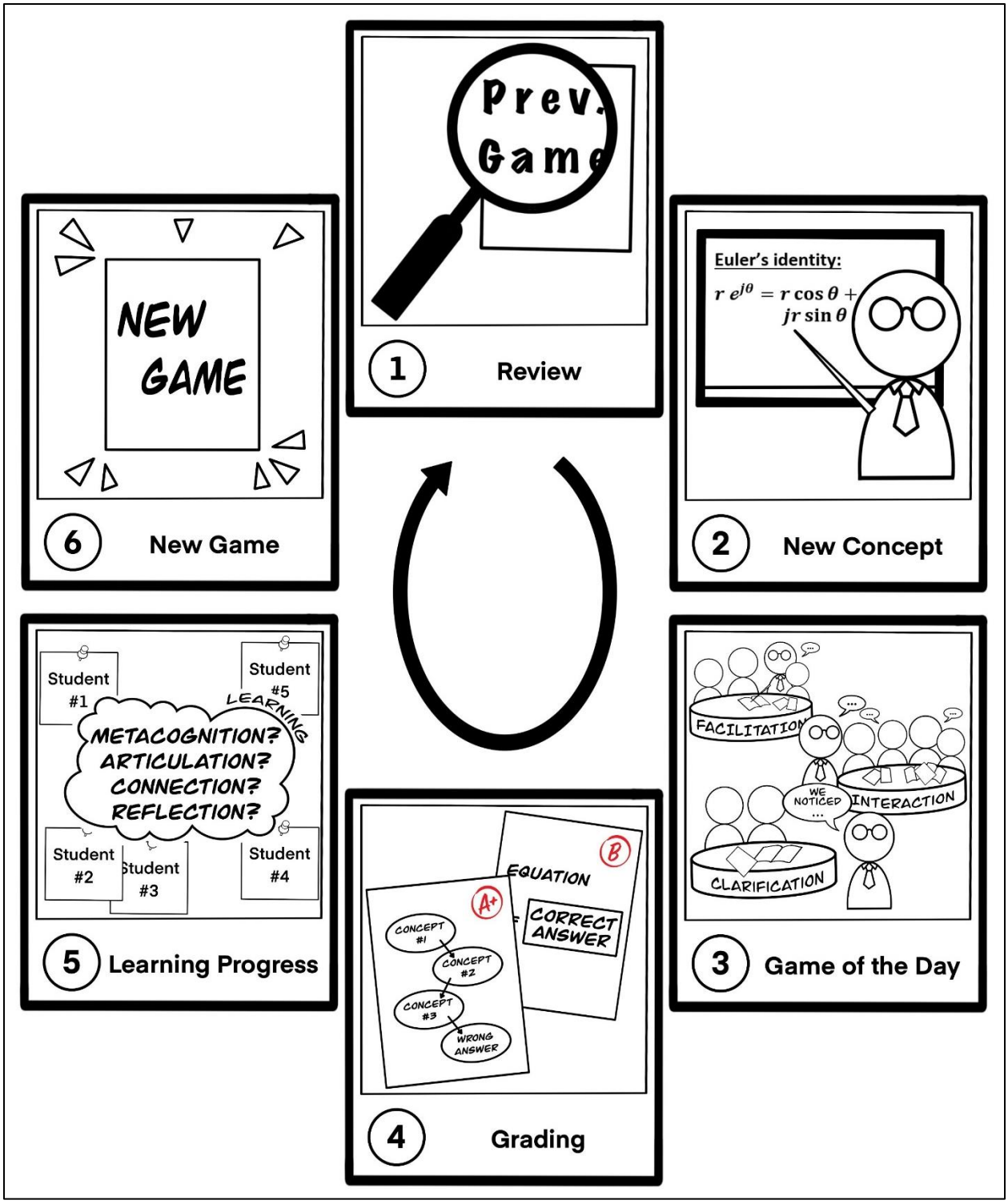

Figure 2. The concept of game, how it is applied, how it is examined, and how it is created.

As we go through the semester, we can detect sparks of genuine emotion and mental growth in specific games. For example, when we introduce a new chapter, the group discussions are livelier in person but shallow on paper. The students have diverging perceptions on the

unfamiliar concepts that they can express better verbally but are unsure of themselves when writing it for the game. These games will require repetitive follow-ups to build upon the students' understanding and confidence in the new material. Similarly, students give better reflection about their learning journey at the end of each chapter or after the tests. They can relate their ideas more cohesively after working on multiple games. We consider each game a valuable reflective activity because it creates a map of the students' processing, problem-solving, and communication growth [8][13][14]. The games create a progressive connection between the syllabus and the students' growth and maturity. The number of games per day increases as the students grow accustomed to this style of learning. The students also grow more comfortable with their mistakes. They will avoid making mistakes, but they will accept it as a learning opportunity.

As the semester progresses, the instructor spends less time on reviewing the previous game and conceptual examples as students become capable, independent thinkers. During this stage, it is the students who lobby for more games. The students will boldly challenge the instructor if a mistake is made and they can defend their statement without referring to the textbook. The students' presentation and ideation skills have also improved to a level where the instruction team can easily pick up the students' message. We call this the emancipation stage and is the goal of our approach. We will discuss the three stages of learning based on our model in the next section.

IV. The three stages to track the students' journeys

Following our model, the students will experience three stages of learning. Initially, the students are uncomfortable because they are challenged to reexamine their understanding of learning and realize the process of learning from their mistakes. It is natural for students to push back and resist the changes. As students came around, they get more comfortable with our style and appreciate the opportunities to learn from their mistakes. Their in-class behavior and attitude changes as they settle into a new identity as learners.

A. Formulization stage

Students are familiarizing themselves with the culture of the class and the platform for experiential learning. They are still driven by grades and focuses on finding the 'correct' equations during the games. They would hide their insecurities by copying other's work. Their questions and verbalization are undeveloped. Their reflections are surface-level and show a lack of critical thinking. Their work is disorganized and hard to follow. Students struggle the most to move on from this stage. One notable sign of growth is when the students let go of their fears and would write their honest thoughts in the games. They also come to accept that they do not have time to copy from examples or learn by mimicry during the games.

B. Maturation stage

Students are now in the practical stage. They handle mistakes differently and show a systematic learning process during the games. They are committed to their own thoughts and

would admit their shortcomings. The team synergy grows and all members contribute to the discussions. They show confidence in their arguments and reflect on their mistakes on their own accord. Students can sometime be confused but they are comfortable with the confusion.

C. Emancipation stage

Students start to show signs of mastery. They understand the goals of the class from theoretical, conceptual, and pedagogical perspectives. They value the freedom associated with not being tied down by mistakes. They show deeper understanding in their communications, verbalism, and capabilities. They challenge the instruction team constructively in well thought out ways. The teams work in unity to overcome challenges. The instruction team shifts away from facilitating the discussion during the games as the teams are self-sufficient.

Concerns usually associated with team-based learning especially in terms of completing the curriculum are greatly diminished by this stage. The students are now autonomous learners. They willingly put in the effort and work effectively as a group to cover topics quickly. The instruction team comes up with a study plan that the teams execute on their own based on their individual strengths and weaknesses. The emancipation stage takes the longest to arrive in but is highly effective. During our many years conducting the two classes, we have never had problems completing our curriculum successfully. The final exam, which tests on the students' cumulative knowledge, is often the least challenging to the students and the overall performance exceeds that of the earlier exams.

V. Students' reflection on their experiences

Both classes often have very positive reflection and feedback from the students. Students in the introduction class would often remember it fondly till their graduation. More than 75% of students in the undergraduate EM class are very successful in their work. During this post-COVID era, students struggle with consistency and persistence. Despite that, our students would move on and still perform well in their upper-level classes. Many of our EM student come to enjoy and have a good time in the follow-up classes although this is not an easy field.

Instructors for upper-level classes would recognize our students by their openness to learning differently and in teams. A good group of former students do keep in contact with the instruction team even after they graduated and moved on with their life. This is a testimony of the bond formed between the students and the instruction team. Included are some reflections from our students on their learning journey throughout the semester. With the students' permission, we are rephrasing their reflections for this paper in accordance to research IRB. Generally, they are kind and encourage us to continue improving this model by providing feedback to be more inclusive.

> *This class was very different. In the beginning, it was very confusing. I had a few difficult classes, and they all had many labs, assignments, tests, and long lectures and notes. This class was not like any other. It reminded me of the freshman engineering class I took with the same instructor. However, this one was more difficult. The games… were there every day, at times we did two. There were assignments, but the focus of the assignments was*

not long deviations, pages of formulation like in my other classes. The assignments built on the material we covered and work on in class. They would just help us to connect and get deeper in our knowledge. What helped me in the class was the team we built, the collaboration, the ever-presence of the games, and the instructor going around and talking to us about the game… In the beginning, the whole thing was annoying, but then we got used to it. The class became fun, challenging in a good way. Now that I am done (the final left), what is strange is that I remember almost all that we did in the class. That is strange, this is not the area that I want to specialize in… but I remember it well, and not in a bad way, it is in a connection to the team, and all the games we did…

I took this class as a mechanical engineer since I have friends who suggested I should do this class, it is fun. Was it fun? Yes. Was it easy? NO! It was not easy, was difficult, at times confusing, and very different from any other class that I have ever had. I doubted myself during the first weeks of the class, and kept asking "should I be here?" My team helped me to stick with it. We worked together in the class on the games, and on homework out of the class. The instructor and the TA were helpful, and encouraging, but would not give us the answers. They would ask questions to lead us to better thinking. It was not what I was looking for, but with their comments, and with our team working together, we did it all. It helped that the class never had high % tests, games, or assignments. They were there, building on each other, and gradually we did it all. Because of the games, I was never worried about the tests, I was confident that I know them and could do them. They made me think, I could eventually do them. Each test would help me push myself a bit further, so I would even learn during the tests. I have decided to think about going to graduate school and work on a connection between Electromagnetism and Mechanical Engineering

I hated Electromagnetism! I am a circuit and electronics student. This class is required otherwise I would never take it. I did not like this material in Physics. I did well in all parts of Physics II. This part was terrible and confusing. In this class, the first few weeks I dragged myself to the class, because I did not want to miss any point or any games. I also thought "Game" is a trick to give us everyday quizzes. Long story short…I was lucky to find a good team. I was suggested to change my team after 2 weeks by the instructor, and I did. The new team and I really clicked. From that point on, I began to change. We face challenges together, we made mistakes (this is a hard material). We figured it out, we laughed and cried together working on homework and preparing for the tests. By the midterm. I could do it all, was not afraid of missing things, and losing points. I wanted to understand it. Now that is the last week… I am not afraid of the final, I do not hate the material… I believe I can do it. I probably do not need this for the rest of my career, but if I must…I am sure I would be OK.

VI. Conclusion

In this work in progress, we are sharing our approach to teaching that has shown promising results during post-COVID era. We have applied this model to our Introduction to Electrical Engineering and undergraduate EM classes. We present our observations, methods, and process. We highlighted the challenges and successes of our model. We share and discuss our philosophy, the students' reception, and the long-term results. We also present reflections from the student detailing their learning journey with us. We are still learning and adapting our model as more COVID-related challenges are identified. As we preach to the students to be lifelong learners, so must our model keep evolving to better cater to the next generation of students who give us the honor of being their learning facilitators.

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