# Investigating Undergraduate Engineering Students' Understanding and Perceptions of Affective Domain of Learning

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# Investigating Undergraduate Engineering Students' Understanding and Perception of the Affective Domain of Learning


## Abstract

This paper is a research paper. Learning is an integral part of our lives. Each one of us learns the same things differently based on our preferred way of learning. We can learn by building mental models; through feelings, emotions, attitudes; and by physical movements. The different ways we learn, or the domains of learning, are broadly categorized as cognitive (knowledge), affective (attitudes), and psychomotor (skills). This research study will focus on the affective domain alone. The affective domain emphasizes learning using emotions, attitudes, and feelings. The affective domain has been categorized into a hierarchy of skills or levels based on emotions. These five hierarchies are receiving, responding, valuing, organization, and characterization. This research study aims at answering the following research question, 'How do undergraduate engineering students understand and perceive learning through the affective domain of learning?'.

A qualitative research design approach was used, and the interview questions were designed based on the six hierarchy levels of cognitive domain. Five participants from varying academic levels were recruited from different engineering disciplines to participate in an online interview (Zoom) of 45-60 minutes. The interviews were audio recorded and transcribed so it could be coded for further analysis. Most students expressed a positive outlook towards learning new concepts in general. However, they also noted a decrease in engagement, interest, and positive feelings when dealing with material taught in an unclear manner, unbalanced demands in a class's structures, and dealing with unengaging closed off teachers or teaching assistants. When responding to a new concept, participants said they will evaluate what they do and do not understand, see what questions or thoughts other students have, review notes, and practice. As students interacted with others, they also felt positive towards a topic that they understood and had a chance to explain to a peer that was struggling with the same topic. Whether students felt positively or negatively towards a concept, participants stayed motivated to learn because they valued their education and recognized that it was necessary to learn, graduate, and/or get qualified for a job of interest to them. Also, when a student must organize or prioritize learning one concept over another, four participants agreed that it has no effect on their opinion of that topic and is just a necessity for time constraints. However, they do feel more comfortable with those topics they spend more time on. One participant stated that they were not good at prioritizing, so they would focus on what concepts seemed most interesting. Finally, with the characterization hierarchical level, participants noted that they became generally more organized, able to break problems down into smaller parts, and able to explain or determine what the root cause of a problem is.



**Keywords:** affective domain, attitudes, undergraduate engineering


## Introduction

Learning is an integral part of our lives. Each one of us learns the same things differently based on our preferred way of learning. We can learn by building mental models; through feelings, emotions, attitudes; and by physical movements. Based on this, the domains of learning are broadly categorized as cognitive (knowledge), affective (attitudes), and psychomotor (skills) [1]. Each domain of learning focuses on one of three ways the brain can be engaged in learning. The cognitive domain is focused on mental processes or thinking, the affective domain focuses on

feelings, attitudes, and behaviors, and the psychomotor domain focuses on learning related to motor skills and physically doing or relating a concept/topic to real world practices [1]. However, this paper focuses only on the affective domain of learning. Researchers interested in learning more about our research on cognitive and psychomotor domain are directed to the studies [2] and [3].

***Affective Domain***: The affective domain focuses on feelings, attitudes, and behaviors, and it can be broken down into five levels of complexity [1]. These five levels, in order or their hierarchy, are receiving phenomena, responding to phenomena, valuing, organization, and characterization [1].

Table 1 – Affective Domain Hierarchy Levels

| Level Number | Level Name | Level Description |
|---|---|---|
| 1 | Receiving | Actively taking in information and being aware of one's feelings and emotions |
| 2 | Responding | Actively participating or interacting with the information and others |
| 3 | Valuing | Being able to find worth in something and being able to express that importance |
| 4 | Organization | Prioritizing certain values over another value to create a personal value system or hierarchy |
| 5 | Characterization | Internalizing the value system -- from the organization level -- and allowing it to guide one's behavior |

The study of this domain focuses on determining what teaching practices produce the most positive attitudes or connections to a concept and how feelings and behaviors change throughout the process of learning a concept/topic. This domain is harder to study and quantify since it is more abstract compared to the cognitive domain. Also, it can be hard to separate positive feelings towards the information and process of learning of a concept versus positive feelings created by generally positive social interactions during certain activities, such as during a laboratory session. Thus, our research aims to find general trends based on students' experiences, perceptions, and/or thoughts towards engineering classes and affective domain connections.

## Literature Review

There is less extensive research in undergraduate engineering pedagogy specifically, and even fewer studies focus on the affective domain in a way that is similar or applicable to this study [4], [5-7]. However, even though these studies were not primarily focused on the affective domain; instead, they were often testing the cognitive domain while asking some affective domain related questions about students' opinions on the new learning technique. Additionally, most of these are more modern studies conducted over forms of online learning. One experiment gave students online modules to aid in their cognitive learning, and during this experiment they also asked how students felt towards this online learning [7]. Students reported high satisfaction levels with online learning and were shown to be as effective as traditional learning styles [7]. Another study focused

on engineering students and mathematics found that student's success in math was correlated to their affective motivations to learn [6]. Another study tested whether online pre-instructional laboratory materials and self-paced e-learning helped students prepare for and master a topic [4]. In this experiment, students were given twenty minutes to an hour and a half worth of pre-lab activities and self-paced e-learning modules [4]. In relationship to student's affective domain, students were found to feel more prepared for the lab but negatively towards the how long they could take [4]. It also found that younger students reacted more positively towards studying with the self-paced e-learning modules [4]. A different study tested how students reacted to fully online laboratory activities [5]. In this experiment students were found to have higher levels of confusion and frustration with the online laboratory, as well as developing the expectation that the knowledge related to the activity would not be useful in their daily lives [5]. Recognize that this study was conducted before the pandemic, so newer studies may find different results related to online laboratories as they are improved upon, and society becomes more accustomed to online work and learning. Knowing students' feelings, attitudes, and behavior and how they are connected to class structure and teaching practices allows researchers and instructors to determine how to augment a class for a clearer and easier learning experience.

There are many related articles that focus on at least one of the domains of learning for engineering students; however, most have different focuses or are not directly applicable to this paper's research. For example, many related studies were testing or creating a tool used to evaluate a class's ability to teach with one or more of the domains, versus testing how to better teach one or all of the domains or discover how students learn with each domain [8-13]. One of these studies created a teaching template for schools so they are more aware of what engineering students should learn during their capstone research [12]. Another study tested the program EvalTOOLs 6 to determine how well a class performed in connecting to each of the three domains and how it may be helpful for determining which domains need more development [8]. One article partially focused on testing or proving that all three domains are connected in the overall learning process -- they are connected [14]. It found all the domains to be correlated when evaluating students' learning, meaning more research should be conducted on how to better connect all three domains in a class structure for deeper understanding, the rest of their findings predominately relate to the affective and psychomotor domain [14]. This idea is directly echoed in another report finding that all three domains need to be intentionally integrated into a class for more effective learning [5]. However, this study in particular had a less conventional – and arguably in-effective – way of assessing students' connection to the affective domain [14]. Instead of asking students to qualitatively describe their experience and opinions or demonstrate whether they agree or disagree with a qualitative statement about their learning experience, this study had instructors assess students' connection to the affective domain [14]. For example, the instructor assessed students discipline awareness in relationship to things such as attendance, participation, and cooperation [14]. While these may be helpful in to monitor in some situations, concepts such as attendance may not be telling of how students approach learning with the affective domain [14]. Also, returning to the idea that the domains are connected is reflected in the fact that many of studies found focus on two domains at a time instead of only one domain at a time [4-7], [14-19]. Several studies exist that research the domains, but they focus on testing a specific class within engineering or non-engineering majors [4-6], [9], [14-16], [18], [20]. Similarly, the studies that focus on math or chemistry classes may not have tested solely engineering students, which could still distort or skew results towards conclusions that may not apply to engineering students overall [4-5], [21]. The problem with these studies is that their findings cannot be generalized for all engineering classes,

but their experiment methods could be adapted and reconducted to learn about general engineering learning. It may also be true for studies that focus on specific engineering sub-disciplines [7], [9], [14], [16], [18], [22-25]. Thus, while there are many studies conducted on the three domains of learning at a collegiate level, there is still much room for further research on undergraduate engineering, especially in relationship to the affective domain. To further this point, two systematic reviews or meta-analysis of studies were also found [17], [20]. One article reviewed 55 publications from 2013-2016 [17]. This study found that the few studies reporting on student's affective domain had too wide a range of measures to effectively code and analyze affective learning outcomes [17]. The other systematic review analyzed 32 articles and found that few articles had used qualitative research methods, as well as a lack of focus on the affective and psychomotor domain in studies over different laboratory modalities [20]. This review also found a weakness in articles' readiness to compare students' achievements where approaches were compared but assessments' compositions had changed "leading to unequal correlations" [20]. This unequal correlation shows there are improvements to be made and more research conducted to study students' domains of learning. It also found that student surveys are important in determining laboratory success and what may need to be improved upon [20]. However, it hopes future research will develop additional approaches that explicitly assess the affective and psychomotor domain [20]. A third paper was found that recognizes this lack of classes developed with affective learning, and it discusses the importance of having classes developed with affective learning in mind [26]. With this as a background, our research study focuses on qualitatively investigating engineering students understanding and perceptions on their learning through the affective domain of learning, as well as provide further evidence to the existing body of research on this topic.

## Method

This research aims at investigating students' responses about their affective connections towards learning engineering concepts. To achieve this objective the following research question was examined, 'How do undergraduate engineering students understand and perceive learning through the affective domain of learning?' A qualitative research design approach was used, and the interview questions were designed based on the five hierarchy levels of affective domain (receiving, responding, valuing, organization, and characterization).

### *Procedure*

The different steps used in this study include IRB approval, pilot interview, participants recruitment, and conducting interviews are described in this section. First, the study and the interview protocol were approved by the Institution Review Board (IRB). The pilot interview was conducted with an undergraduate engineering student randomly selected from the population to assess the effectiveness of the questions. Following this interview, minor changes were made to the interview protocol and the interview questions were then finalized. Third, the participants were recruited from a large public research university in the United States. The initial screening survey was sent to several undergraduate engineering students. Following students' responses to the survey, five participants were selected from different engineering disciplines (Please refer Table 2 for more information on participants demographics). Finally, these five participants were invited to participate in an online interview conducted using Zoom. The choice of conducting interviews online was made to ensure all students who received the screening survey could participate without concerns of transportation and increased flexibility as the interviews were conducted during summer 2023. Additionally, conducting the interviews online did not change any of the interview

procedures in comparison to if we had held interviews in person: all interviewees were asked the same questions, each interview was audio recorded for further transcription and review purposes. Also, all interviews were blinded (only audio and no video), to avoid biases based on visual appearance. All interviews conducted ranged between 45 to 60 minutes. The interviews were recorded and later transcribed. More details on the data analysis will be provided next.

Table 2 – Participants' Demographics Information

| Participant | Class Standing | Engineering Discipline | Race/Ethnicity | Gender Identity |
|---|---|---|---|---|
| P1 | 6th Year Senior | Mechanical Engineering | Asian | Trans Male/Trans Man |
| P2 | Junior | Computer Engineering | Hispanic or Latin X | Female |
| P3 | Sophomore | Aeronautical Engineering | White | Female |
| P4 | Sophomore | Biomedical Engineering | Asian | Male |
| P5 | Senior | Industrial & Systems Engineering | Black/African American & Hispanic or Latin X | Male |

### *Data Analysis*

Each interview recording was transcribed using Zoom's transcription function, and then the transcriptions were (re)read with the recording and small errors in the transcription were fixed. Additionally, time stamps were added to the interview transcripts for later review as needed. After transcription, NVivo was used to code and organize the data for further analysis. The interviews were coded in relationship to each interview question asked [27-28].

## Results, Analysis, and Implications

In the interviews conducted, the affective domain was often connected to the participants' feelings, attitudes, and behaviors towards engineering education, certain teaching practices or concepts, how those emotions affected their study, etc. The following section examines each interview question individually. Each question starts with how the question directly connects to a hierarchical level. Then, they present the participants' responses, analyze those responses to understand participants' perception, and further discuss the implications of the responses and resulting trends.

Participants were asked two introductory open-ended questions (Q1-Q2) related to their perceptions about learning. Next, participants were asked three questions (Q3-Q5) about how their affective domain changes when learning different or new concepts. Then, participants were asked five questions (Q6-Q10) directly related to the five hierarchical levels of the affective domain (see Table 1 for details on hierarchical levels). Finally, participants were asked (Q11) which of the three domains they preferred to learn with and why. It should be noted that this interview consisted of questions about all three domains, and the results were split into three papers to better emphasize the findings related to each domain of learning. In this paper, we focus only on the affective domain

of learning. Readers interested in understanding more about the research on cognitive and psychomotor domain are directed to the other papers from this project [2-3].

***Q1*: *How do you perceive learning as a process?***

Learning is an integral part of our lives. Each one of us learns the same things differently based on our preferred way of learning. In this question, students share their perceptions on learning as a process.

Overall, P1 and P3-P5 noted that examples, practice, and repetition were remarkably important in the learning process.

> P4: *You have to continuously either learn it in class, and then keep practicing those same concepts. You just have to keep practicing it if you want to learn.*

Please note that the other participant (P2) did not say they were against this belief; instead, they noted that learning is a never-ending process.

> P2: *I don't think learning is really something that ever ends because there's limits to the things that we can do. We kind of approach the limit of perfection asymptotically, like we can get super close, but we can never quite reach it.*

P2 noted that practice and example problems are important in some of their later responses. P1 also noted their belief that learning is non-linear, individualized, and may come from being taught or from self-teaching oneself a concept. P3 emphasized the need for one to understand why things happen the way they do when learning new concepts. P5 also expressed a fondness for learning and finding example problems on YouTube as they often must teach themselves different concepts. P5 specifically credits this need to instructors' desire to challenge students by not giving many examples and/or not explaining concepts in enough detail. P4 also stated that watching YouTube helped them better understand a concept better but noted that YouTube is not the only thing students should use to learn, as practice and repetition is also important.

> P5: *I understand professors want to challenge kids and see what they can do, but I feel a bit lost when it comes to learning new material. Honestly, YouTube was my best friend, especially for specific examples or general theory.*
>
> *P4: I feel like you have to go through the steps. Like you can watch a 15-minute YouTube video but you can't stop there. You have to like continuously learn it in class and then keep practicing those same concepts either the night after or the day before class or whatever you just have to keep practicing it if you wanna learn.*

Based on the participants' responses, it is observed that the participants feel they would benefit from additional practice, repetition, and examples when learning a new concept. Three of the five participants specifically noted their willingness to conduct further research outside of class for a better understanding of concepts and/or to find additional examples. Thus, instructors and researchers might explore the specific types of examples and practice problems that aim at enhancing students' learning experiences through the application of the affective domain of learning. This may include ideas such as determining specific types of examples and practice problems that would be most helpful to students learning, or how many problems should students be required to solve versus the number of problems for students to practice. The engineering students' responses also show that they desire additional information, examples, and explanation

of engineering concepts for the development of their mental models. Also, these responses indicate that participants understand that learning new concepts takes time and have complex connections to a variety of application problems. Additionally, keep in mind that as P1 mentioned, some learning can be individual, and some learning is better suited for a traditional classroom learning style. Thus, research on the usage of different learning modalities (online, in person, or asynchronous) in engineering with a focus on the affective domain of learning might be beneficial to teaching engineering topics more efficiently. A few studies on engineering education with online components testing learning within the affective domain were found in research for this report [4-7]. Another study reached a similar conclusion of hoping to further test and research e-learning approaches [25]

***Q2***: ***What, in your opinion, are some different ways or approaches that you can learn by?***

Overall, all five participants noted that taking notes, seeing problems worked out, and trying them on their own were important approaches to learn from. Three of the five participants (P1, P3, and P4) also mentioned some form of hands-on learning being important. An excerpt from participant 1 is below.

> P1: *I think things like note taking and repetition work for a lot of things, but I also think hands on learning and applications are very important to understanding a lot of concepts.*

Participant 2 (P2) made a light connection to the affective domain by expressing frustration with graded homework noting that it adds pressure to get the right answer. They further stated that they would be "excited" to do homework if it was participation based instead of solely accuracy based.

> P2: *Something that always makes me really struggle with homework problems is the fact that it's a lot of pressure to try to have to get everything a hundred percent right the first time. I've found it the most helpful whenever my professors will assign homework problems that are purely for participation. I feel like it made me excited to do the homework because I wasn't dreading it and staying up all night stressing about it.*

P4 and P5 also distinguished auditory learning versus straight visual learning with examples and slideshows. P1 also specifically mentioned being able to ask questions about a concept to deepen their understanding. Finally, P4 and P5 noted trying to understand each part of the whole equation and/or process. An excerpt from P4 is below.

> P4: *For me, I'm more of a visual learner than auditory, so I like to see the steps and how they're done step by step. I just have to see it. Even for like chemistry, like a reaction mechanism with the arrows and where the electrons are moving.*

All five participants value the cognitive domain of learning and three out of the five participants (P1, P3, P4) explicitly connected to the psychomotor domain of learning. On the other hand, only P2 made a connection to the affective domain, though it was a tangential connection to how P2 would be more excited to do homework with less pressure of getting a decent grade. This shows how participants are most familiar with the cognitive domain, less aware of the psychomotor domain, and least aware of the affective domain. Thus, additional research over the affective domain needs to be pursued.

***Q3***: ***When you are learning a concept or topic, how do your feelings, attitudes, and behavior change internally towards the concept during that learning process?***

All participants, except P4, noted feelings of confusion, frustration, and being overwhelmed when learning a new concept. These negative feelings were noted as being especially strong if it is a difficult concept, if participants continue to get questions wrong, and/or if they have limited time to learn it. An excerpt from participant 2 (P2) is below.

> P2: A*t first, I tend to feel really confused and frustrated trying to get over that initial hump of understanding because it can be really frustrating to get that answer wrong like four times in a row.*

Participant P5 noted that they become so frustrated at times that they do not want to learn anymore but will return to the concept as deadlines approach and concerns over grades rises. On the other hand, these participants also listed a variety of positive ways they can be motivated to learn and noted how their attitude towards new content can change for the better.

> P1: *If I'm coming into something and I'm excited about it or I'm already interested in it, then learning it tends to be easier. It can also help if I have maybe a good teacher, good mentor, a couple friends in the class, a support structure, or I otherwise come to find the subject matter interesting or very applicable. But I definitely think that personal feelings towards a subject or exercise do influence how well I do and how well I perceive I'm going to do on it.*

Participants P2 and P5 also noted a feeling of wonder, enjoyment, and satisfaction arising as they begin to understand the concept and know they have mastered a new topic. In response to this question, participant P4 was an outlier having few negative feelings associated with learning a new concept outside of being stressed.

> P4: *I like a good challenge. I like the hustle. So, when I come across something that is pretty hard to learn, I take a minute to like figure out what you can do and what you can't do. But I always approach it with a positive attitude. A lot of people can get stressed out and overwhelmed with content coming at them, but that's like the beauty of learning. You just have to embrace it and accept that you're not going to know everything and ask others for help. So, I just take it with a positive approach no matter how stressed I am. I just got to keep pushing forwards and try to learn it because the only person holding you back is yourself.*

These emotions appear logical as difficult or new concepts can be overwhelming and frustrating. With most students having similar changes in their affective domain during the learning process, it should be easier to alter coursework for the most positive learning process for most people. However, further investigation is required to determine how instructors should alter their coursework and teaching styles to help students understand new material easier with a focus on the affective domain of learning. For example, in a parallel paper of this project on the cognitive domain [2], if students were taught how to take notes more efficiently, then would students find engineering classes to be easier to understand and thus more enjoyable? Similarly, in relationship to the affective domain, further investigation could be conducted to determine how labs or other activities should be formatted, with an intent to make them less confusing and more enjoyable. Alternatively, participants P2 and P5 noted feelings of wonder, enjoyment, and satisfaction as they understand new concepts better. Research on when and how these feelings develop may be important in determining how to make the necessary modifications to the coursework and foster these types of emotions. It might be more encouraging for students to continue to put efforts into

learning if the positive feelings can be maximized as well as felt more often by engineering students.

***Q4***: ***How do your feelings, attitudes, and behavior change internally when receiving information, responding, and understanding the value of the concept -- relating the learning to your character or personality?***

Since this question is related to each participant's own character or personality, only light connections or trends were found in the students' responses. Participants P3 and P4 mentioned their need to break down information piece by piece and take breaks when getting overwhelmed. An excerpt from participant P3 is below.

> P3: *When a lot of information is thrown at me, I can get really, really stressed out, so I have to take a step back and think "I need to break this down and learn individual pieces and parts". I really have to take a step back. And of course, no one's expected to have something completely memorized and understood in a day: I just have to take a step back and understand that some things take time.*

Participant P3 also mentioned their struggles with procrastination and how they become frustrated and impatient when they cannot understand a new concept. However, this comment seemed more related to the receiving information and responding part of Q4, versus being a comment about their character or personality as compared to other engineering students. P4 also mentioned that they feel they sacrifice a lot to learn engineering, as compared to their colleagues.

> P4: *Compared to me and the other average engineering student, I would say I make a lot of sacrifices in the sense that I keep my studies number one. Like I go to office hours or ask for help and spend extra time working and studying at night. I just feel like I put a little bit of extra work in.*

Another light trend observed is that both participants P4 and P5 mentioned feeling like they ask more questions than others when trying to understand a concept or get clarification. Finally, P1 and P2 found themselves to be generally more interested in learning than other students, with P2 feeling they had much more passion for the concepts being taught than other students.

> P2: *I feel like I'm a lot more excited to learn. I feel like a lot of people I know are really apathetic towards school and learning. Like a lot of my friends have told me that they're only doing it so that they can make money, and I feel like I don't really feel that way. I feel really passionate about learning. I always think it's nice to learn new things even when I really really struggle with them.*

Participant P1 also found themselves likely to pay less attention if they were less engaged in class and more open minded and attentive in classes that are more engaging.

> P1: *I tend to very much enjoy learning. Generally, it's rare that I will walk into a class and be like, oh, I hate it already. I try to keep a very open mind about learning when I'm more engaged, whether it be discussion or being asked questions, or just being queried of "Hey how do you do this?" or "How far do you think you've gotten this?". I tend to give it more thought, be more engaged, and overall become more open towards that class or more positive towards it. The less engagement integrated in a class, the less attention I'll tend to pay in it.*

In this section, students' feelings, attitude, or behavior when receiving information, responding, and understanding the value of the concept is explained. With all these trends or connections being marginal, it would be interesting to further investigate to determine whether they are common among engineering students. If these feelings are common, then instructors might want to emphasize the importance of breaking down concepts as students learn them, asking questions, and/or make sure to acknowledge the hard work and time their students are putting into learning new concepts. This might provide students with positive feelings or attitude when learning a concept. On the other hand, when it comes to participants P1 and P2's intrinsic feelings about being excited to learn, it is unclear how to make other students feel the same way. However, P1's note about appreciating when instructors engage students more frequently during class may be a short-term way to keep students engaged. Although this is not an intrinsic desire to learn, it may help keep students more involved in the learning process, and this may develop into an intrinsic desire to learn though it would need further research. If further investigation could be done to determine how to make students passionate about learning with a focus on affective learning in engineering, then perhaps learning as a whole would be easier for students.

***Q5***: ***How do you feel about this affective change as you learn, and does this change have any influence on your learning?***

As seen in the participant responses discussed earlier, participants acknowledge that they experience feelings as they learn concepts in engineering. As a part of their response to Q5, all participants agreed that affective domain influences their learning. Excerpts from participants P1, P2, and P4 are below.

> P1*: I think a lot of times, my work quality will reflect how I feel towards the class. So, classes that balance their demands and have a lot of engagement will be able to keep my attention. If there's very little engagement, then I tend to struggle to focus and sometimes won't go to those classes.*
>
> P2: *I think that excitement and positivity from learning previous concepts makes me more likely to stick out that initial frustration period. I think being able to do something in a class has encouraged me to branch out to try more subjects that I wouldn't have tried otherwise.*
>
> P4: *Math becomes the best class whenever you understand it, but it becomes the worst class when you don't. So, my attitude changes once I understand the content.*

This question was relatively straight forward; however, participant's responses demonstrated an interesting trend in how participants feel towards their emotions and learning as a process. Most participants first indicated that their understanding of a concept is what influences their feelings, attitudes, and behavior towards the concept. Then, participants, such as P1, stated that based on those feelings, they will put more effort into their work. This increased effort, positivity, and excitement to learn makes it easier for participants to endure the "initial frustration period" as mentioned by P2. Thus, a participant's affective domain and their learning appears to work in a cyclical nature that can act as a positive feedback loop when students feel they understand a concept and therefore put more effort into their work, which helps them get through the confusing parts of a new concept and increases their confidence in their ability to understand confusing concepts. Or think of this as the academic version of trying to chase the high or positivity a student felt from understanding previous concepts. Unfortunately, this has the ability to work in the

opposite direction as a negative feedback loop. If a student feels they never fully understand a concept, they will feel negatively towards the concept and the class, and overtime may disincentivize a student to try hard to understand later concepts. Further investigation could be directed to better understand the cyclical nature of how learning affects the affective domain and vice versa. Once this is fully understood, educators can determine how to format their classes and classwork in a way that emphasizes positive emotions and actions within this cycle of influencing students' learning. Additionally, instructors should do their best to encourage positive emotions in their students because, as P2 said, having that breakthrough and understanding a concept makes them more likely to work through the initial frustration period of not understanding a difficult topic. Therefore, if students continue to get "stuck" in that initial frustration period of not understanding a variety of concepts, they may become less likely to persevere and work hard to understand new concepts in the future.

***Q6***: ***How do you receive information when you are learning? What motivates you to learn concepts?***

This question relates to the first hierarchical level of the affective domain *receiving*, which focuses on an individual actively taking in information and being aware of one's feelings and emotions [1].

All participants, except for P3, noted that a general interest in learning or a specific interest in the class or concept motivates them to learn.

> P2: *I just feel like I want to have more knowledge. Learning new things makes me feel good and it makes me feel like I have a better understanding of the world, so I just want to keep learning more for that reason.*

However, participants P1, P3, P4, and P5 also noted how learning to graduate and get a job are important motivators.

> P1: *I've sampled the field and industry that a lot of these classes are preparing me for, and I really enjoy it. I want to be able to do it well and I want to be able to get a job in those industries. It's knowing that I need that background to be able to do what I want to do after graduation. Some of my motivation has definitely been to finish class so I can get my degree and be done with school.*

Participant P3 also talked about how important it is to learn concepts well when you first learn them as these concepts can be built upon later in that class or future engineering classes. Finally, P4 said their family was a great motivator for them to do well in their classes.

> P4: *It's more of a personal answer with my family. They motivate me the most to keep pushing to be successful and not just for myself but for my family. I do have a passion for what I'm learning, but I also don't want to waste my time and the money my family is putting in for my college education. Anytime I'm not feeling motivated or like lazy I just think back on the sacrifices my family has made, and I just want to keep pushing forward for them.*

First, all participants, except for P3, noted some form of an intrinsic interest in a concept or general intrinsic desire as a factor that motivates them to learn. If instructors intentionally focus on developing and strengthening students' intrinsic desire to learn, then students may feel less worn

down by their class loads. This would make learning more enjoyable and hopefully lead to more students successfully completing the course. Secondly, all participants except for P2 noted some form of self-serving motivation (relating to graduating and getting a job) when receiving information and learning concepts. Thus, it may be motivating to emphasize how receiving information and understanding a concept is important for students to successfully complete the course, graduate, and become successful engineers. Doing this would help keep students' long-term goals in the forefront of their minds and hopefully keep them motivated to learn when working with difficult topics. Also, this connection to future goals and delayed gratification is becoming more important as this idea was touched upon in various questions by participants. It would also be interesting to use further investigation to determine how many engineering students find these future goals to be motivating and/or how it connects to their learning with a focus on affective domain. Finally, P4 was the only participant to verbally mention being motivated by other people. This brings into question whether it was more uplifting motivation or based around familial expectations and pressure. However, this would require further investigation to determine what percentage of engineering students receive these types of motivation and its influence on their learning. In summary, when it comes to receiving information, participants perceive learning as being intrinsically interesting and/or beneficial to their long-term goals of graduating and getting a job in their field of engineering.

***Q7: How do you engage with others when sharing or transferring knowledge? Also depending on the person you are responding to, do your feelings, attitude, and behavior towards that concept change?***

This question relates to the second hierarchical level of the affective domain *responding*, which focuses on an individual actively participating or interacting with the information and others [1].

While this was an open-ended question about sharing or transferring knowledge, it should be noted that participants P2, P4, and P5 all spoke as if they were directly explaining a concept to another person, similar to the role of a tutor. Participants P2 and P4 started by focusing on creating or trying example problems with another student, with P4 making sure to note that they try to lead the other student towards an answer without directly telling them what to do or why.

> P4: *How I help other people is usually with a practice problem, but I'll try to like not just to give them the answer. I'll try to walk them through the process and my reasoning behind it. Then, if they get stuck on a certain area between those steps, I'll try to go more in depth as to like what's going on in that step, like why that's happening.*

Then, these participants work to help that student understand it on a deeper level by connecting it to earlier concepts, letting them ask questions, and try to clarify the topic overall. On the other hand, P5 does not start with an example problem. Instead, they focus on first determining what the other person knows and what they do not understand. Then, they would focus on the foundation of the topic, find patterns, and show them their own diagrams or flow charts. P5 would similarly try to answer questions, expand on the topic, and collaborate with the other students. This is similar to the process P1 and P3 follow. However, P1 and P3 emphasized how they work to determine how they understand a concept or solve a problem differently than their peers. This way they can understand another way to solve a problem and/or another perspective on the concept.

P1: *I try to see what their take is because everybody explains things differently and sometimes that's more helpful than a professor who says the same thing every time. Then, we can work* together*, talk about it, compare what we see, discuss, and get help if needed.*

When it comes to how this sharing of knowledge affects the affective domain, responses are similar to the responses to Q3. While participants did not make all of the same points, there were many similarities in the tone of the responses. For example, P1 mentioned how frustrating it can be for themselves and another student if they both cannot figure something out. On the other hand, all participants noted positive feelings associated with being able to work with or explain something to another student. P2 and P5 went as far as to say it made them excited to learn and was fun.

P5: *When collaborating with others, it's like a spark. It's like playing around and it's pretty fun. Feels like we're investigating or like scientists.*

In response to this part of Q7, participant P2 also noted their appreciation for learning other peoples' perspective on a problem as it may change the way one sees and approaches similar problems in the future. P1 and P4 noted their increased confidence in understanding and/or confidence for upcoming exams if they were able to help another student understand the topic.

P4: *I love trying to help other people understand content that I understand. Also, you get to practice it more and you feel overall more confident when going into an exam.*

In summary, it is safe to conclude that all participants seem very adept with the hierarchical level *responding* and putting their knowledge into practice. Connecting these responses to some of the results of the parallel study cognitive paper [2], participants show once again that they appreciate seeing multiple perspectives and ways of solving problems. These new perspectives are seen as important and interesting, and discussing them can make the students' learning more enjoyable. Thus, it may be beneficial to have additional example problems and/or videos explaining different solution methods or concepts from a different perspective. Additionally, it may be helpful to students' learning experiences and the affective domain if more time is intentionally dedicated for collaborative work with their peers. What is interesting is how positive their responses were towards helping and collaborating with other students. Perhaps it would be beneficial to have instructors give students practice problems, and as students get the correct answer, those students can help other students who might need help in solving that problem. This would create opportunities for more collaboration, ensure students could explain concepts or solutions in depth, and foster those positive emotions associated with helping others and collaborating and in return further enhancing their learning.

***Q8: How do you find value or worth in your own learning?***

This question relates to the third hierarchical level of the affective domain *valuing*, which focuses on an individual being able to find worth in something and being able to express that importance [1].

Participants P1-P4 all noted that they find value in their learning when it is connected to a future job and/or seeing how a topic is applicable in real life. P2 specifically said they find certain topics or classes to be of value knowing that it will make their job easier in the future.

P2: *I kind of just find value in my learning from being able to do more things. Like a lot of abstract math knowledge isn't very useful day to day, but it's a valuable skill. So having*

*more knowledge about say computers lets me do more. The more I learn about computers, the easier my job becomes, and more doors open in the professional world to help me do what I want to do. So why wouldn't I try and learn the most?*

P4 also mentioned learning is valuable when it allows them to help others currently or in the future.

> P4: *I find value when helping other people understand the content too. I feel like I have more value learning about things with real applications towards bettering other people and their lives.*

Participants P1, P2, and P5 also noted finding value in personal enjoyment of learning, having a challenge, growing mentally, and gaining a new skill. P1 made sure to note that although they find value from both reasons of personal worth and monetary value of knowledge, they try to keep personal worth reasons at the forefront of their mind as it keeps them more positive than thinking only about the long-term monetary value of their knowledge.

> P1: *I think there's the personal worth and the monetary worth. A lot of times I just enjoy learning, it's just self-betterment, it's adding value to my skill sets and is generally a net positive for me. In terms of like monetary value you have these skills that help you get a job: I wouldn't discount that as a value of learning. But I think for me, I try to make the personal value of a skill or knowledge more important because then it reaps better rewards in terms of your ability to execute your mental health and how happy you are currently learning.*

> P2: *I don't know, I kind of just find value in my learning from being able to do more things, have more knowledge.*

> P5: *I guess I like being challenged, having a growth mindset is honestly great and not such a fixed mindset. I'd say some of these classes are very good in that they help you think outside of the box: they want you to continuously grow.*

For this question, there seems to be two main categories within the students' responses. Either the response was related to futures jobs and applicability, or it was connected to more intrinsic reasons such as personal enjoyment of learning. The first category is probably the easiest response for instructors to make connections to. When introducing new topics, instructors should explain why and how the topic is applicable to students, in their daily lives or for their careers. Instructors may explain when and where a concept is used in the professional world. However, as P1 noted, this monetary worth is not always the most helpful when it comes to finding value in learning and short-term goals or motivation to learn. With a similar thought process, this monetary reasoning may not be as helpful if students are not as far along in their engineering degree and/or if they do not feel as close to graduating and working in a professional job. Thus, those intrinsic values should still be upheld and emphasized. However, further investigation will be required to determine how best to get students to value their learning for their personal reasons.

***Q9***: ***When learning a concept, you may have instances where you might have to prioritize the value or worth of learning one aspect over the other. How do you deal with such a case? Then, after making that choice, did your opinion or feelings on that concept change towards the concept you spent more or less time on?***

This question relates to the fourth hierarchical level of the affective domain *organization*, which focuses on an individual prioritizing certain values over another value to create a personal value system or hierarchy [1].

While all participants, other than P2, noted that they will prioritize studying concepts based on their order or importance, participants had a few different ways of deciding which topics were most important. Participants P1 and P5 mentioned that they focus on topics that appear frequently in class, whether that be in lectures, homework, or quizzes. Furthermore, P1, P4, and P5 all specifically mentioned focusing on topics that will be emphasized or worth the most points in a test. P1 also created a scenario where they have two tests and need to prioritize studying for one test over another. In this case, P1 said they would decide based on which test is worth more and which class they have a better grade in.

> P1: *If I have like two different subjects and I can only study one, then it will come down to which exam is worth more? Which one do I have the better grade in? Which class can take the hit?*

Participants P1 and P4 noted that they will focus on studying topics they do not understand well or are not as proficient in applying.

> P4: *I just look at the practice problems and see what questions I feel confident in and which ones do I not feel confident in? And I'll practice primarily the ones I don't feel confident in because that's probably what would stop me on the exam versus the ones I do feel confident in. I'll just see what I am personally struggling with, and what can I do to help make sure I can do it on an exam.*

Participants P1 and P3 mentioned focusing on topics that will be most important in the future and/or topics that will be directly built upon in future units or classes. On the other hand, P2 said they were not good at prioritizing and would instead just start studying the topics they found most interesting. P1 also mentioned occasionally being guilty of studying the most interesting topics first; however, it is not common for them to do this. Generally, participants had minimal feelings towards the content they did or did not decide to focus on. P1 and P2 said they felt neutral towards both groups as all the information was important, it was just a matter of time management.

> P1: *I don't think so. Usually it'll be a base of, I know these are both important and it's just come down to I am a single person with only so much time. Usually, it doesn't mean that one is less like interesting than the other. I don't think it changes the feelings I had going into a subject if I have to prioritize one over another, it's just difficult.*

> P2: *I wouldn't say that my feelings dramatically change in any way. I always want to go back and learn the other thing as well unless it's the case of it truly is just a thing that I need one time, right? I feel like my feelings don't really change that much based on my prioritization of the things that I have to learn.*

Similarly, P4 and P5 said they felt neutral towards the topics they did not have enough time to focus on. However, P3-P5 noted more positive feelings towards the topics they decided to study. They felt more confident and prepared for the test, as well as P3 mentioning that these topics seemed less daunting than before they had a chance to study them. Finally, P3 mentioned that they can feel less comfortable with their ability to apply topics they have little to no time to study.

> P3: *I think topics can scare me because they seem so complex. But once I start reviewing them, they're not so scary, and I'm glad I took extra time to review it. I'll feel more comfortable with my ability to apply those topics I spend more time on. But if I don't spend enough time with a topic, I might start to feel uneasy and not sure if I can apply those anymore or if I can solve those topics or understand them as well anymore.*

With the first part of this question, it was found that four out of five participants have little to no problem prioritizing one concept over another. From those participants, three of them base their decision on what they believe will be most important to know for a test or exam. This shows that most of the participants' value system or hierarchy for organization is focused on grades and what an exam will cover. Thus, instructors should be clear about their tests' concept breakdown, as well as make sure they give the most important topics the most questions or make them worth more than questions on other topics. The following trends were only followed by two of the participants. However, these weaker trends indicate that instructors should remind students to study topics that will be important later in their engineering degree, as well as topics that they do not understand well. Only one participant, P2, noted that they were not proficient in determining which topic should be prioritized. To combat this, professors might want to directly tell students which concepts are most important as one study found it led made students more likely to remember those concepts [29]. Throughout these interviews, engaging classes have been mentioned a handful of times. Therefore, more engagement from the instructors with the students and interactive classes may help students understand and learn important topics.

***Q10: Sometimes when you are learning a topic you try to integrate some aspect of that learned topic into your character or personality. Has this happened to you and if so, would you share an example?***

This question relates to the fifth hierarchical level of the affective domain *characterization*, which focuses on an individual internalizing the value system – from the *organization* level – and allowing it to guide one's behavior [1].

While these responses were very individualized, P1 and P3 mentioned being able to break down ideas or steps and being able to decide how to work more efficiently.

> P3: *I just think "How can I do this efficiently?" I just need to decide what's most efficient and most worth my time and energy.*

Participant P1 also said that being in a more technical field has made them a more organized person. P3-P5 also talked about being better at learning and taking things step by step. P4 furthered this point by saying they felt they were better at applying those steps and the logic of why or how things work when applying that information in a different situation. P4 also felt they had become better prepared to take in a lot of information or content without being stressed or overwhelmed. They also felt better at asking questions.

> P4: *I kind of carry the same attitude I have towards school, like don't stress yourself out. Like in school whenever our instructors are giving a bunch of content you have to learn it all in a certain amount of time. I feel like many people get overwhelmed with stress, but you try your best, take a deep breath and keep going. And I'll go back to ask my professors questions.*

Participants P2 and P5 also felt they were better at determining the root cause of a problem and thinking systematically about the steps needed to find a solution.

> P2: *I feel like doing proofs gives you a really different way of looking at the world. feel like that's something I've tried to integrate into my brain, just trying to come up with a process to show other people that this is like infallible. It makes me a lot more conscious of the things that I'm doing in my algorithms for computer science stuff because I try harder to justify them to myself in my brain. I try to think of all possible edge cases where my algorithm could fail.*

Overall, efficiency, organization, logically taking ideas step by step, determining a solution, and becoming less stressed and overwhelmed by a lot of information were mentioned by participants. Since these ideas are so individualized, more data is required to determine how common they are and whether there are additional skills or topics that students have internalized. Then knowing which topics are most internalized, it will be easier to determine which skills many engineering students have, and which ones may need to be improved upon. For example, if data shows that engineering students have not internalized organization as a skill, then it may be important to have instructors emphasize organization within their class. This way, students will see the importance of being organized as it is important when working on larger-scale projects in the professional world. On the other hand, the skills that are commonly internalized by students will not need to be emphasized by instructors, and mentors or bosses in the professional world would have a better understanding of what skills young engineers typically have when starting their first internships or jobs.

***Q11: What learning approach do you think you learn best with and why?***

Three participants, P1, P4, and P5, found the cognitive domain to be the best approach to learning, while P2 and P3 found the affective and psychomotor domain to be the best approach, respectively. However, it should be noted that most participants had some trouble picking one domain over the others, but P3 and P4 were more confident in their domain of choice than P1, P2, and P5. P1 found the cognitive domain best for taking in and understanding new concepts; however, they found a combination of all three domains to be very important. P1 also noted that sometimes which domain is most important depends on the subject being learned.

> P1: *That's really hard because I learn best with a combination of them, and its very subject dependent for me. I think overall, the one that catches the most subjects is the cognitive domain or mental models. But personally, I feel like a combination of these domains is important because maintaining motivation helps you execute that, and then sometimes having a physical reference or having somebody show you something physically helps you build those mental models better.*

Participant P2 has made clear that they do not often take notes, thus it makes sense that they would not find the cognitive domain to be the most important domain. Instead, participant P2 finds the affective domain to be the most important domain to learning.

> P2: *I feel like being motivated and excited to learn is probably the way that I am able to learn so much. Being able to create mental models of things is great and very helpful to learning anything, but I feel like the most important thing is just wanting to. I feel like if I didn't have that, then the other things wouldn't come along with it.*

Participant P3 found the psychomotor domain to be the most important as it directly relates to real life experience in engineering jobs. An excerpt from participant P3 is below.

> P3: *I would say that psychomotor is probably the most realistic. If we're learning something in college, and if we're learning all of that only on paper, and we have no real-life experience with that topic, we are not going to be successful when we get jobs out of college. We wouldn't be successful when we have to apply anything we've learned if we don't actually know how to apply it, especially as engineers.*

P4 also noted that the cognitive domain is most important as it can be used to learn a wide range of topics, as well as aid in retention of information. P4 also stated that the cognitive domain is the primary domain they have currently used. Finally, P5 referenced that the cognitive domain and mental models is best for doing well on exams.

> P4: *I think mental models are the best because that's pretty much all I've used so far basically from freshman year of high school to now sophomore year of college and it hasn't failed me thus far. It's just really good because you're creating your own mental models that like unique to you. So, it kind of helps you with anything you're learning, and I've used it for all of my subjects or courses.*

> P5: *Using the cognitive domain and techniques helps me a lot just because whenever I'm doing anything it's normally on paper and exams are formatted similarly on paper. Every class is on paper and taking exams is on paper, so definitely writing everything out helps me a lot.*

Overall, three out of five participants found the cognitive domain to be the most important or their preferred domain of learning, and four out of the five noted their general appreciation for the cognitive domain, mental models, and taking notes. This shows the importance of the cognitive domain and mental models, and the importance of students learning how to take notes and develop mental models early in collegiate education. On the other hand, only P2 chose the affective domain, and only P3 chose the psychomotor domain. Of these two participants, P3 was confident in their decision, while P2 had trouble deciding on one domain over another. Additionally, P2 chose the affective domain partly because they do not typically take notes. This helps show how undervalued the affective domain can be. Additionally, as the affective domain is centered around feelings, attitudes, and behaviors it is typically more difficult to quantify, describe, and understand effectively. This all helps prove that more research on the affective domain, quantitative and qualitative, is necessary. If researchers can better determine engineering student's perceptions on affective domain and how they change in the learning process, then instructors can better alter their classes to keep students interested and excited to learn. Similarly, researchers may determine how to avoid students' negative emotions – such as being overwhelmed, frustrated, or mentally fatigued – making the overall learning process more enjoyable.

**Major Trends, Takeaways, and Implications**

As a review of the findings and implications found in these 11 questions, the following section will focus on major trends, outlier responses, and their implications. It is clear that participants were not as aware of the affective domain as the cognitive [2] or psychomotor domain [3]. This can be seen by participants response to introductory questions such as Q2. Participants were able to clearly describe or give examples of learning as it relates to the cognitive or psychomotor

domain; however, there were no direct connections to learning with the affective domain. This helps demonstrate the need for additional research and awareness of the affective learning domain within engineering and pedagogies used in engineering. A few of the literature reviews reviewed in the introduction also found a lack of research on related qualitative studies and the affective domain [17], [20], [26].

All participants desire additional examples, repetition, hearing other explanations or perspectives, and having concepts related to other concepts. These concepts were collectively mentioned by participants over fifty times through their interviews. This shows that participants have a strong desire to learn and have a deeper understanding, but they feel they are not getting a wide enough range of examples, practice, and perspectives. Additionally, most times these ideas were mentioned, participants noted having to do their own additional research outside of class to find these things and deepen their understanding of the current topics they are learning. While research experience is an important skill for engineering students, many of the participants also indicated their concern of learning things incorrectly from inaccurate sources online. Therefore, instructors might provide additional helpful resources, references, examples, diagrams, and connections to other concepts for students to reference and practice. This way students will have a reliable source to review additional perspectives, examples, and practice problems. A few sources were found that also recognize the importance of additional examples, demonstrations, and perspectives and/or found them to be helpful for students [6], [18], [30]. Other studies found students appreciate classes online learning components or modules, and one hypothesized that students like this modality because it allows them to review and practice at any time [6-7].

Participant P2 brought up an interesting point when it comes to repetition and practice, specifically when it comes to grading homework. While all participants saw the value in practice, P2 greatly dislikes how most homework is graded for accuracy on a student's first try as it put more focus and stress on getting the answer right the first time and getting a good grade, versus putting the focus on learning and understanding how to do a problem correctly. Therefore, P2 would rather have homework be given for participation and to focus on learning. Engineers in the field must be able to apply math and engineering concepts safely and accurately, but they are able to make tests, run analytic software, and have other engineers to check and debate each other's work. Instead, it might be interesting to test how homework for participation, homework valued at a lower overall grade percentage, homework with multiple attempts, and so on may affect final grades and overall learning.

Many studies have been conducted relating to homework; however, they are rarely directly focused on the connection homework has to the affective learning domain [31-33]. One literature review did recognize that each student has their own ideal learning environment that may not be accommodated for because it is not the standard widely accepted learning environment [30]. This may be the case with P2 feeling participation-based homework would be more effective to their learning process. This study also found some evidence of a positive feedback loop with homework quality and higher motivation to do homework as discussed in Q5. This furthers the idea that more research needs to be conducted on how to make undergraduate engineering homework assignments more enjoyable and effective at helping students learn.

The next takeaway relates to what participants are motivated by. All participants noted confusion, frustration, and becoming overwhelmed by the number of new topics they are required to learn. While there were many motivators given, the more easily controlled motivators are deadlines,

knowing topics will be built upon later, good academic support systems, and a desire to graduate and get a certain job – as compared to less controllable motivators such as the intrinsic desire to learn or having family motivate a student. Thus, to keep students motivated, instructors should be sure to set clear and fair deadlines, show how topics are applicable, and continue to create safe learning environments. Of these ideas, making connections to a concept's applicability and getting a job might be the most important motivators as it was mentioned by all participants between the questions on motivation and valuing education. Additionally, while confusion and frustration cannot always be avoided when learning new concepts, feelings of being overwhelmed may be more manageable. All participants mentioned breaking down concepts into more digestible parts at one point or another during their interview. Therefore, to avoid feelings of being overwhelmed instructors might attempt to break down concepts for students into simpler portions. As discussed in more detail in Q5 (How do you feel about the change in your feelings, attitudes, and behavior when interacting with new information, and does this change have any influence on your learning?), without this motivation and breaking down of concepts students may become less likely to persevere and work hard to understand new concepts in the future.

Other studies around engineering pedagogy have found other sources of motivation for students to learn and complete assignments. One study found that having students perform self-assessments of the strengths and weaknesses within their understanding of a class or concept motivated them to work on the concepts they did not understand [34]. Another study found that tutoring increased students' motivation to learn, reach their academic goals, study, ask questions, and practice their skills from class [35]. Two other sources found evidence of positive feedback loops – as discussed in Q5 – being a source of motivation as it relates to homework and grades [6], [32]. One study found that students' success in mathematics correlated with their affective motivations to learn [6]. Similarly, the other study found that students with more quality homework were more motivated to learn and do work [32]. This in turn led to those students completing more of their homework, receiving better grades, and therefore being more motivated to continue working hard [30]. It also found these students had more or higher intrinsic motivations and were more likely to delay the immediate gratification of not doing studying and doing their homework [32]. A third source specifically talked about how these feedback loops may turn negative and how it may impact students' learning [26]. This idea of a positive or negative feedback loop further emphasizes the need for additional research to determine how to build and strengthen students' motivations to learn. When it comes to things that dissuade students from learning, becoming overwhelmed with new information was frequently mentioned by participants. Other studies found that instructors giving students access to the PowerPoints used during lectures – or other forms of guided notes – helped avoid this mental overload [36]. This study found that taking notes during class requires much more mental effort than reading or learning in general [36]. This means having access to a slideshow allows students to focus on understanding the theory or math behind a new concept, instead of trying to listen, comprehend, pull out important points, and record them at the same time [36]. Therefore, students may become less mentally drained during class and less overwhelmed if they have access to the notes for all their classes. This is especially true when considering how much extra time students may need to spend outside of class to re-teach themselves the lecture if they are taking notes instead of focusing on an instructor. There are other similar experiments or literature reviews on things like guided notes [37].

Another major takeaway is the positive impact on participants when working with classmates as it relates to Q7 (How do you engage with others when sharing or transferring knowledge?).

Participants had positive connections to hearing others' perspectives, collaborating to understand a concept in depth, feeling more confident for an exam, and/or directly helping another student learn. The only neutral to negative emotions mentioned were continued confusion and exacerbated frustration when a group was unable to figure out a difficult topic or problem. However, seeing as participants enjoyed collaboration, instructors should encourage or require students to work together for at least some assignments. Perhaps it would be beneficial to have instructors give students practice problems, and as students get the correct answer those students should be requested to help other students that might need help in solving the problems. This would create more collaborative environments, ensure students could explain concepts or solutions in depth, and foster those positive emotions associated with helping others and collaborating. These neutral to positive responses also bring up the question of what can make group projects or similar collaborative work so problematic for other students. Perhaps it is an issue of scheduling when to meet with others. Maybe students need to be able to form their own groups, i.e., pick their own partners, when working together for the most positive experience, but also how would that affect their cognitive understanding of a concept, if at all. Answers to these questions could make group work much more enjoyable, and if it was more enjoyable students may learn more and get more work done overall. Here are two studies that examine different forms of cooperative group work and some of the problems with its implementation [38-39]. Other studies have worked to develop management strategies for group work and see how social skills – such as cooperation – can be developed in a classroom [40-41].

While participants may enjoy helping explain concepts to other students, studies have found that being tutored is another positive learning place for students to learn and collaborate with others [18], [35]. One study created a tutoring system: it was found to be a much more personal way for students to learn and interact with the content and another person [35]. The other study had students meet one-on-one or in small groups for tutoring with a member of the school's faculty [18] While this may be hard for a university to implement, it also showed a positive learning experience.

A smaller trend found in participants responses is when participants must prioritize learning some concepts over others, there were no negative emotions connected to the concepts participants did not spend time reviewing. Instead, participants recognized that it was predominately a matter of time management, and their main change in attitude was feeling more confident and prepared towards whichever topics they focused on. Thus, there should be little to no concern that students will feel negatively about topics they focus less on studying. Instructors must dedicate efforts in organizing a class schedule, so concepts are better spaced out. Hopefully, students would then have less need to prioritize learning certain concepts over another and would instead be able to review them all in full.

This research made it apparent that more quantitative research needs to be conducted to clarify what feelings, attitudes, and behaviors are trends and which are outliers. That data will also show trends as they relate to engineering disciplines and/or other demographics. These trends would be valid starting places for additional quantitative and qualitative research to be conducted which may determine the most and least effective teaching strategies, hopefully making learning engineering easier and more enjoyable.

## Conclusions

In this qualitative study, five participants were individually interviewed online and asked to respond to 32 open ended questions related to the cognitive, affective, and psychomotor domain. These interviews were transcribed and coded to organize and find trends within their responses. Participants were not as aware of the affective domain; however, all participants desired having access to additional examples, perspectives, connections between concepts, and greatly value practice. Participants also acknowledged that they were willing to conduct additional research outside of class to find these things. They also acknowledged that they are concerned about the validity of this information found on the internet. To stay motivated to learn, participants' responses were focused on an intrinsic desire to learn, self-serving reasons such as getting a job after graduation, and/or external motivation from family. With this motivation, participants were able to overcome their feelings of confusion, frustration, and being overwhelmed with the number of concepts they must learn. Participants were also found to have positive affections towards working with other students, hearing their perspective or solution method, and helping teach other students. They have no negative feelings towards concepts they are not able to prioritize because of time constraints. Additional quantitative research is necessary to determine whether these findings are common, how these trends may relate to students' engineering disciplines and demographics, and which teaching methods will maximize students' learning with a focus on affective domain and minimize frustration and confusion.

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