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Course Material or External Factors?: Assessing Student Perceptions that Impede Learning in Engineering Education

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Course Material or External Factors?: Assessing Student Perceptions that Impede Learning in Engineering Education

Engineering courses are mathematically inclined and rigorous in nature. Numerous pedagogical methods such as communication strategies, learning environments, and visual supplements have been designed and implemented to promote student learning, engagement, and success in rigorous topics. As such, engineering students are encouraged to allot sufficient time to recurrently process lecture notes, attend office hours, or inquire about ambiguous technical content to fully assimilate course material. In this study, students enrolled in two engineering courses (Rigid Body Dynamics and Engineering Analysis) were evaluated to identify which aspects (course material or external factors) generated the most predicaments during a semester span. The following challenges were available on the open-ended, self-developed survey: a) lack of knowledge in calculus, geometry, or trigonometry, b) did not study enough, c) course material was too difficult, d) lack of interest in the course, e) rigor of the course, and f) overwhelmed by other courses. The open-ended responses did not identify any pedagogical methods as critical factors to understand course material. Results revealed that 11.9% of the students enrolled in Rigid Body Dynamics and 0% of the student in Engineering Analysis thought the challenges experienced throughout the semester were due to the difficulty of the course. However, 50% of the students enrolled in Rigid Body Dynamics and 47.1% of those in Engineering Analysis mentioned that the challenges experienced resulted from not studying enough. To this end, 47.6% (Rigid Body Dynamics) and 38.2% (Engineering Analysis) of the students invested less than 2 hours per week studying when no assignments were given, and mentioned the lack of focus and negligence as the non-academic factors generating poor academic performance.

I. BACKGROUND AND MOTIVATION

Academic Resources

Higher-education has implemented numerous resources with the intention of promoting student learning, engagement, and success. Several of these resources include distinct pedagogical methods, learning centers, mentorship and advising roles, and campus spaces.

Faculty members have devoted decades of research designing and implementing pedagogical methods such communication strategies, creating learning environments, and utilizing visual supplements that foster student comprehension and scholarship abilities [30], [31], [32]. Two of the most common instructional methods widely incorporated in engineering disciplines are Problem-based learning and Project-based learning [18], [33]. These methods have been utilized towards developing learners' self-directed and critical thinking skills [28]. Marquez and Garcia developed and implemented the ECNQ model (e.g., acronym for Engage, Communication, Names, and Questions) as an active communication approach to engage engineering students in the classroom [15]. Studies have further identified visual cuing as an effective instructional method that promotes learning at faster rates [1], [5], [6], [7], [8], [12], [16]. De Koning *et al* reported higher academic performance due to visual cuing, while Marquez and Garcia reported that visual supplements enhanced student comprehension of complex engineering concepts [14].

An alternative resource utilized by undergraduate engineering students is partaking in research opportunities given its short- and long-term benefits [6], [8], [4]. According to literature findings, 53% of students majoring in STEM majors are involved in research activities [5], [6], [7], [8], [13]. Carter *et al* and Gregerman reported significant research and professional confidence by those involved in research venues, while Hurtado *et al* reported that research venues clarify post-graduation career options [4], [31], [32].

Student learning, engagement, and success has further been promoted in higher education via advising and mentoring roles. According to Gordon, mentorship roles are a critical component for student success given that 20-25% of entering freshmen are undecided about a specific major, while 75% will transition to other majors at least once prior to matriculation [9]. Marquez and Garcia developed a mentorship model called RCDD (e.g., acronym for Relationship, Commitment, Desire, and Disseminate) which identifies four critical components in the transformative process of supporting student success in undergraduate research [13]. They further developed and implemented a model termed IBIEE (e.g., acronym for Identify, Build, Integrate, Evaluate, and Extend) which is centered on nurturing a disposition from faculty members to identify and recruit engineering students into their groups [13]. The IBIEE model was developed with the intention of recruiting underrepresented minorities into research venues, which seem inaccessible due to cultural background, lack of proper academic guidance, and various institutional-based factors [13].

Pascarella *et al*, Tinto, and Thomas have identified that the social and academic fabric of an institution also plays a critical factor in student success [20], [27], [28]. Additional resources on campus such as academic advising, learning centers, and counselling and disability services have allowed students to overcome academic misinformation and/or preparedness [22]. Similarly, Andre *et al* confirmed that campus recreation programs and facilities reduce stress and anxiety levels, increase academic success, and improve mental and physical health [2].

II. PURPOSE OF RESEARCH

External Factors

Despite the plethora of resources available promoting academic success, institutions continue remedying predicaments with retention and passing rates, which postulates the premise that students may be contending with external, non-academic factors.

For instance, according to the retention rates from Texas Public Universities, The University of Texas Rio Grande Valley (UTRGV) has an average freshman retention rate of 75% (Table 1) [29]. These values are relatively low compared to institutions across the state of Texas such as Texas A&M University (92%), UT Dallas (88%), UT Austin (95%), and Texas Tech (85%) but higher than many other institutions in the state. Furthermore, statical measures indicate that retention rates of first year (full-time) students in the College of Engineering and Computer Science have been at an average of 60% between the Fall of 2015 and Fall 2019 (Table 2) [29]. However, those trends declined in the wake of COVID-19. Retention rates of incoming students, for instance, declined to 53.3% in the Fall 2021, while retention rates within the institution similarly plunged to 60.9%.

Table 1. Texas Public Universities Freshman Retention Rates. Freshman entering in Fall 2015 through Fall 2018 (usnews.com/best-colleges/rankings) [29]

Texas Public University	Average Freshman Retention Rate
UT Austin	95%
Texas A&M University	92%
UT Dallas	88%
University of Houston	85%
Texas Tech University	85%
University of North Texas	79%
Texas State University	77%
Texas Woman's University	76%
Sam Houston State University	76%
UT Rio Grande Valley	*75%*
UT El Paso	74%
UT San Antonio	73%
UT Arlington	72%
Texas A&M Kingsville	68%
Texas A&M Commerce	66%
UT Tyler	64%
Texas A&M Corpus Christy	58%
Texas Southern University	54%

Table 2. UTRGV College of Engineering and Computer Science First Year Full Time Freshman 1st Year Retention Rate [29]

Cohort	Retention Within College	Retention Within University
Fall 2015	62.3%	78.2%
Fall 2016	66.6%	77.0%
Fall 2017	64.7%	74.9%
Fall 2018	69.4%	78.5%
Fall 2019	67.2%	79.0%
Fall 2020	53.3%	60.9%

In this regard, not only have retention rates declined at UTRGV. Passing rates in introductory courses have significantly dropped during COVID-19 (Table 3) [29]. For instance, CIVE 1101 had passing rates in the Spring 2019 and Spring 2020 of 78.9% and 91.9%, respectively. However, this past academic year, which was surrounded by COVID-19, passing rates fell significantly to 69.9% in the Fall semester and 63.1% in the Spring semester [29].

Table 3. UTRGV Passing Rates in Intro to Engineering and Computer Science Courses [29]

Semester Course	Spring 2019	Fall 2019	Spring 2020	Fall 2020	Spring 2021
CIVE 1101 - Introduction to Civil Engineering	78.9% (n=83)	84.4% (n=122)	91.9% (n=74)	69.9% (n=156)	63.1% (n=84)
CMPE 1101 – Introduction to Computer Engineering	68.8% (n=32)	78.2% (n=110)	48.2% (n=54)	64.2% (n=95)	75.0% (n=48)
CSCI 1101-Introduction to Computer Science	62.8% (n=94)	75.8% (n=244)	70.2% (n=151)	78.0% (n=282)	67.6% (n=148)
ELEE 1101 – Introduction to Electrical Engineering	72.2% (n=36)	70.4% (n=81)	63.3% (n=49)	75.0% (n=88)	39.2% (n=51)
MANE 1101 – Introduction to Manufacturing Engineering	71.4% (n=21)		90% (n=20)	68.0% (n=25)	86.7% (n=15)
MECE 1101 – Introduction to Mechanical Engineering	67.4% (n=95)	75.2% (n=206)	70.6% (n=85)	69.3% (n=215)	57.9% (n=76)

As such, the purpose of this study is to understand whether academic factors, particularly the instructor's pedagogical strategies, or students' external factors are generating the most predicaments in the classroom during a semester span. Other external factors may include students being overwhelmed by other courses, family related challenges, financial distress, or not spending time studying/preparing for assignments and exams.

III. METHODS AND ANALYSIS

For this study, students enrolled two engineering courses (Rigid Body Dynamics and Engineering Analysis). in a public, minority-serving institution in Texas, were evaluated to identify which aspects generated the most predicaments during a semester span. In this context, the authors employed a qualitative research framework for data collection. The primary method of data collection consisted of a self-developed, ten-item survey in which questions were intended to understand classroom experiences. Nonetheless, the study poses the following limitations: (a) small sample size; (b) self-developed survey instrument; (c) convenient sampling procedure. The following challenges were available on the open-ended, self-developed survey: a) lack of knowledge in calculus/geometry/trigonometry, b) did not study enough, c) course material was too difficult, d) lack of interest in the course, e) rigor of the course, and f) overwhelmed by other courses.

The administered survey consisted of ten questions:

Question 1: How confident were you about the course material at the end of the semester?

Question 2: What gave you the most problems in the course?

Question 3: How many hours did you study for the class (each week) when there was no homework assignments or exams due?

Question 4: How many hours did you study for the class (each week) when there was homework assignments or exams due?

Question 5: How many times were you absent from class throughout the semester?

Question 6: If you were absent from class at least once throughout the semester, tell us why.

Question 7: What were your expectations at the beginning of the course? Were those expectations met?

Question 8: After completing the course, how important is it to understand basic calculus, physics, geometry, and trigonometry?

Question 9: What non-academic factors would you say are keeping you from improving your academic standing?

Question 10: If you could do something different to improve your understanding of the material, what would it be?

IV. RESULTS & DISSCUSSION

Findings

Findings are presented below and highlight themes and/or important data that was ascertained during the study. The open-ended responses did not identify any pedagogical methods as critical factors to understand course material. Results revealed that 11.9% of the students enrolled in Rigid Body Dynamics and 0% of the student in Engineering Analysis thought the challenges experienced throughout the semester were due to the difficulty of the course. However, 50% of the students enrolled in Rigid Body Dynamics and 47.1% of those in Engineering Analysis mentioned that the challenges experienced resulted from not studying enough. To this end, 47.6% (Rigid Body Dynamics) and 38.2% (Engineering Analysis) of the students invested less than 2 hours per week studying when no assignments were given and mentioned the lack of focus and negligence as the non-academic factors generating poor academic performance.

Question 1: How confident were you about the course material at the end of the semester?

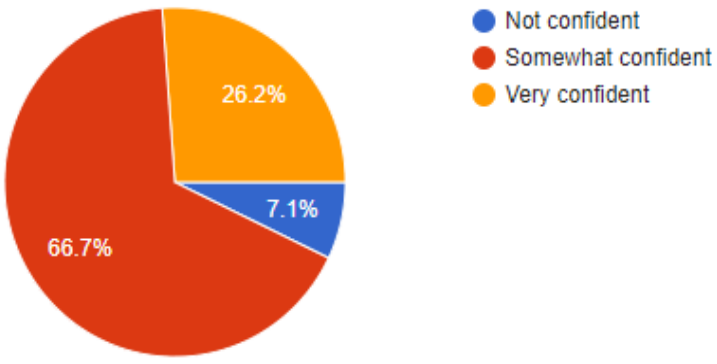

Figure 1. Survey Findings for Question 1

For question one (Figure 1), roughly 26% of the students indicated that they felt 'Very Confident,' about the course material, while nearly 67% indicated that they were 'Somewhat Confident.'

Question 2: What gave you the most problems in the course?

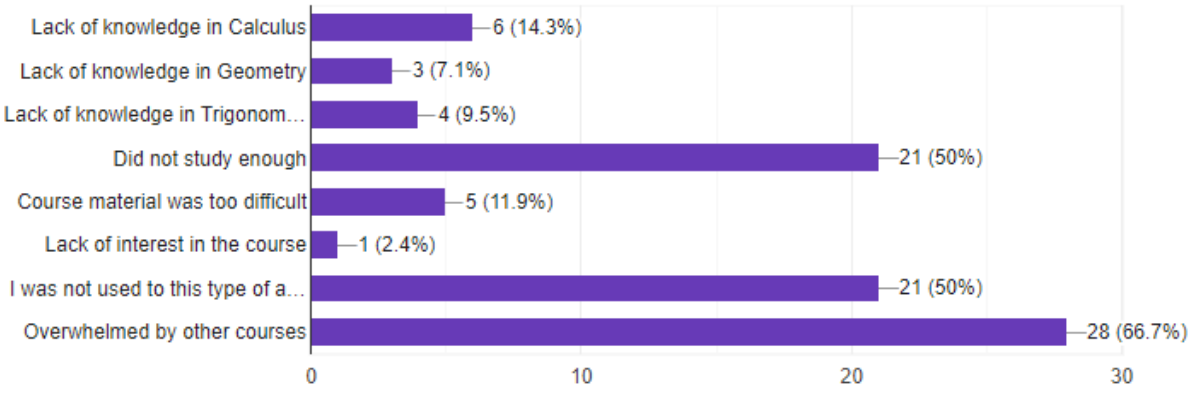

Figure 2. Survey Findings for Question 2

As evidenced by the chart above, nearly 67% of the students surveyed indicated 'Overwhelmed by Other Courses' as the top problem that impacted their learning (Figure 2). The same number of students (21) indicated that they 'Did Not Study Enough,' and/or were 'Not Used to this type of approach,' respectively. Despite the level of rigor of the course, only 5% of the students noted that the 'Course Material was too Difficult.' Open-ended responses to Question 2 provided additional student insight into problems that impeded their learning.

Overwhelmed by Course Workload and Other Responsibilities

> *"Two of my other classes required me to teach myself, since the professors from those classes taught poorly. This took a lot of time away for me to study effectively in this class."*
>
> *"It was an interesting course and I wish we had more time to understand the concepts better or go in greater detail. In the end however I lacked the time needed to sit down and understand due to work and other courses piling up. I still need practice with my geometry and trig, but it was an interesting class that I plan to go back at in the summer either through my notes or through the textbook."*
>
> *"Taking multiple classes, having 16 hours made the course load difficult. At times the material did not make sense the first time around so having to take even more time to understand the concepts was very difficult. Moreover, this class was more challenging than any other course I had taken."*
>
> *"I had not properly managed my time between work, school and personal family matters this semester, and as such I fell behind in this course. Unfortunately, I fell behind in many*

of my studies, however it was the dynamics course that received the least attention. The course material is very interesting, and every lesson has been great, my lack of understanding came entirely from lack of practice. Although the course material was challenging it was entirely doable it just required much more time than what I had put into it."

The responses listed above the time management challenges faced by students enrolled in the course. Like those from other public universities, the students found themselves having to balance multiple work, school, family responsibilities, which greatly affected their overall academic performance.

Question 3: How many hours did you study for the class (each week) when there was no homework assignments or exams due?

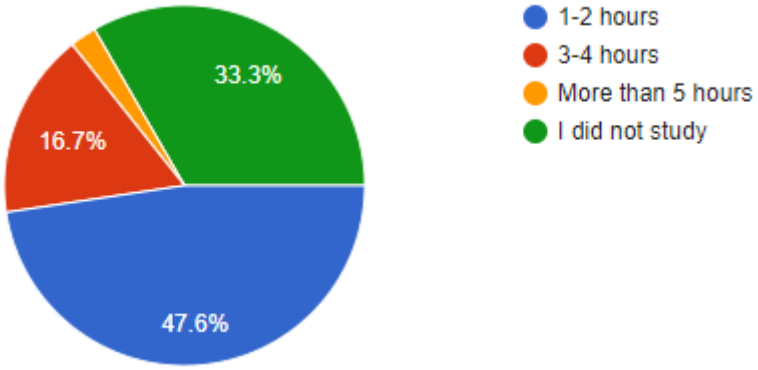

Figure 3. Survey Findings for Question 3

For Question 3, roughly 48% of the students indicated that they studied about 1-2 hours per week. Only 17% of the respondents studied between 3-4 hours a week, while one-third revealed that they did not study at all (Figure 3).

Question 4: How many hours did you study for the class (each week) when there was homework assignments or exams due?

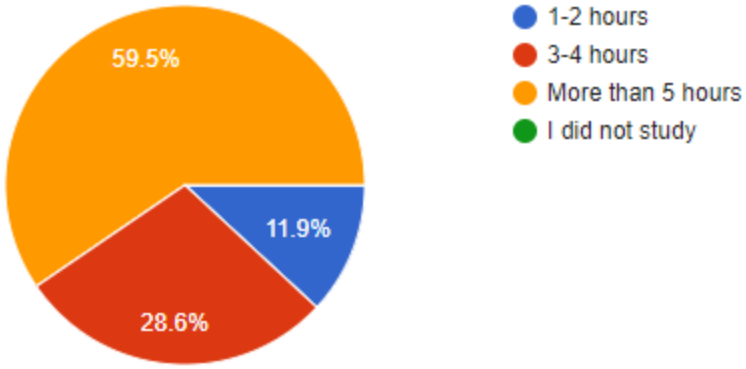

Figure 4. Survey Findings for Question 4

Question 4 further sought to learn about students' effort to study on weeks that homework assignments and/or exams were due. Roughly 60% of the students revealed that they studied more than 5 hours, while 12% noted that they studied between 1-2 hours (Figure 4).

Question 5: How many times were you absent from class throughout the semester?

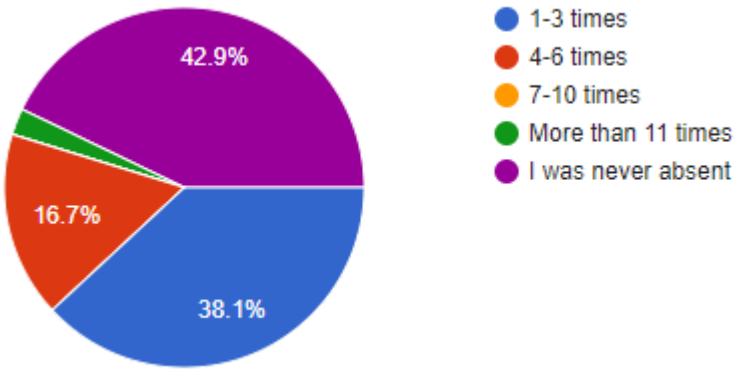

Figure 5. Survey Findings for Question 5

For Question 5, students were asked to select the number of times they missed class. A total of 43% of the students did not miss class, 38% missed 1-3 classes, while roughly 17% were absent between 4-6 times during the semester (Figure 5).

Question 6: If you were absent from class at least once throughout the semester, tell us why.

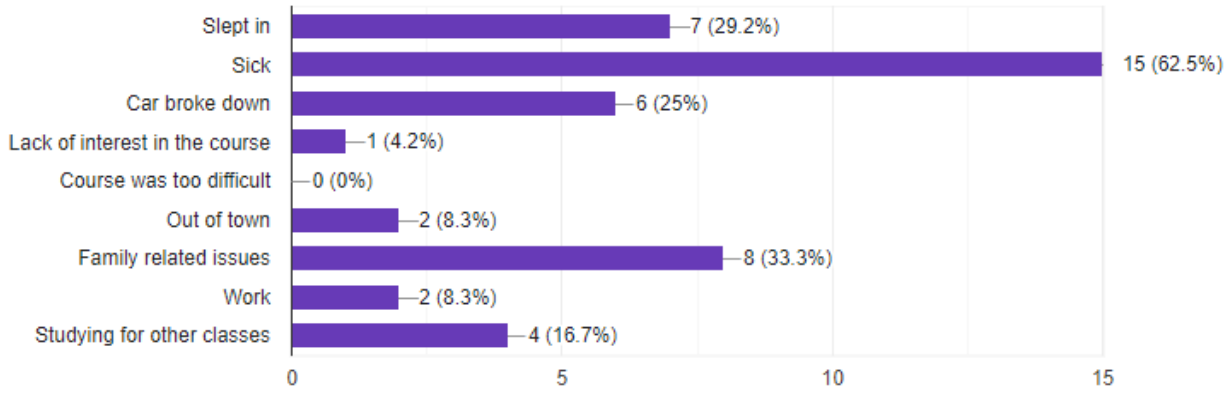

Figure 6. Survey Findings for Question 6

Question 6 asked the students were asked to select the number of times they missed class. A total of 43% of the students did not miss class, 38% missed 1-3 classes, while roughly 17% were absent between 4-6 times during the semester (Figure 6). Open-ended responses to Question 6 provided additional insight into the reasons that influenced students' decision to miss class.

Reasons for Missing Class

> *"Since I have a few other classes on the same day I have the dynamics class, on some exam days I would choose not to attend class so that I could let myself have more time to make sure I was understanding material for those other classes."*
>
> *"My old truck did not start a couple times, but got it fixed. Also, after we attended a funeral of a family member, my wife got sick, so I stayed home in case it was Covid even though I had no symptoms."*
>
> *"I was absent from this class for several reasons, but never because I did not want to go nor because of lack of interest. Sometimes I work very late and had family issues that I had to take care of, my car was in and out of the shop (still currently in). So, I was always stressing and was not getting enough sleep."*
>
> *"The main times I was absent was due to either having an upcoming exam I had to focus on or literally struggling to get out of bed due to anxiety and or stress. The other time was due to a Covid scare that you were made aware of."*

The students' responses above shed light on the circumstances, challenges, and scenarios that influence and affect their decision to miss class. Conflicting coursework responsibilities, tending to familial and personal issues, and technical mishaps are the most selected as obstacles to attending class. Moreover, physical, and mental health related issues such as COVID and anxiety and stress were also significant issues faced by some students.

Question 7: What were your expectations at the beginning of the course? Were those expectations met?

A question of interest for the authors was to learn about the students' course expectations and whether they were met. Nearly all the students indicated that the course met their expectations. Below is a presentation of a few of the responses that highlight students' experiences and feedback related to their expectations:

Overcoming Expectations

> *"My expectations were for it to be a difficult class, but not this rigorous. Even though it was tough and sometimes it seemed impossible, I managed to learn and overcome much of my doubts on how I was doing in the class."*
>
> *"I expected this course to be extremely complicated since I've had other classes (Physics for Engineers 1) where they throw you equations and give you problems and expect you to be able to solve and understand everything. I'm glad this was not that type of class."*
>
> *"I expected this course to be extremely difficult, which is true. However, Dr. X did an outstanding job in teaching the material that it just felt like 'ripping a Band-Aid off.' It wasn't easy and it required a lot of hours of studying outside of class, but overall it wasn't impossible to get through."*
>
> *"I expected for this course to be an advanced version of statics. Knowing that it was with Dr. X, I knew it was going to be both challenging and fun. Although I expected it to be difficult, I did not anticipate the amount of time needed to complete and comprehend each assignment. Having taken this course with Dr. X, the expectation of going through a rigorous and fun course was met."*
>
> *"I honestly was expecting the standard dynamics course all the upper classmen have taken, but my expectations were far surpassed. The course was MUCH more difficult than anticipated but I enjoyed it, more than any course I have taken so far."*

As evidenced by the responses above, most of the students had high expectations of this course. They were presently both surprised and challenge by the rigor of this course. Although the rigor was considerably more intense than previous courses, they students appreciated the challenge and noted that they not only learned but also found the course enjoyable. This underscores the fact that rigorous courses, if taught effectively, can be both educational and appealing to learners.

Question 8: After completing the course, how important is it to understand basic calculus, physics, geometry, and trigonometry?

Question 8 inquired about the value and importance of understanding basic calculus, physics, geometry, and trigonometry to experience course success. All the students surveyed noted the knowledge in the fundamentals in the disciplines above are vital to comprehending engineering concepts taught in the course.

Understanding Different 'Languages'

> *"I think understanding basic Calculus, Physics, Geometry, and Trigonometry is very helpful and time-saving as it aids one's ability to more easily comprehend what is going on and to see different perspectives of the problems; to think of the different approaches one can take and basic ideas of what one has and what to expect when solving a problem."*
>
> *"Super important. Everything felt connected. Which is something I see more often in upper engineering courses but usually not in a sophomore level course."*
>
> *"Very important. I definitely had to go back and relearn some of the things that were mentioned in class, silly things like integrals and some other stuff from calculus. It made this course more challenging not fully having a good foundation on those topics."*
>
> *"Understanding calculus, physics, geometry, and trig is integral to passing this course. A strong background in the aforementioned concepts is required to grasp and apply the basics of dynamics. Otherwise, it's like trying to read a different language with no understanding of it whatsoever."*

All students surveyed agreed that it is essential to have familiarity with basic calculus, physics, geometry, and trigonometry. Responses revealed that having a grasp in these disciplines saves valuable time and effort in acquiring new taught course material and engineering concepts.

Question 9: What non-academic factors would you say are keeping you from improving your academic standing?

In regard to Question 9, students were asked about non-academic factors that impinge their academic standing and achievement. Financial circumstances, familial responsibilities, and mental health issues were all cited as factors that affect learning.

Confronting Financial Circumstances and Mental Health Challenges

> *"I worked after school so it would sometimes limit the amount of studying for the class. I also had to take care of my nephews after school since my parents and siblings worked. Moreover, having severe anxiety hindered my ability to focus on all my classes."*
>
> *"My family's financial stability is a major factor that affects my academic standing. I must have a job to provide for myself and my family which takes time away from studying and resting. My family members depression is another aspect that affects me mentally and emotionally. Sometimes it is hard to stay motivated when you are constantly worrying and afraid."*
>
> *"During this semester, I've noticed that I have started to get really distracted with other things and my procrastination got worse. I think I would have done much better in the class if I didn't do that so much."*

"Work has been a very time-consuming aspect of this semester, while I know I should prioritize my education first I have spent more time working than anything else this semester. This however is NOT an excuse to skip assignments or grades, my time management ultimately falls on me and I just found myself unable to focus on my school assignments in the evening when I got home."

Based on the data collected, it is evident that students are faced with many unique challenges and circumstances that impair their ability to excel in the course. Several students noted that they struggle with mental and emotional health issues that are a detriment to experiencing academic success. As such, it is important for faculty members to consider these issues and provide support, advice, or resources that enable students to manage issues that impact their learning.

Question 10: If you could do something different to improve your understanding of the material, what would it be?

The final question sought to provide students an opportunity to reflect and consider actions that could be taken to improve future outcomes. Based on the responses, spending more time studying and leveraging university resources were the top actions indicated to help improve learning outcomes.

Leveraging Office Hours, Improving Study Habits

"Visit office hours more, or at least arrange something with the professor, such as zoom or possibly opening a discord server to discuss in real time. Definitely changing my study habits along with improving my math skills."

"Review over the lecture notes as soon as the class ended so that I can make sure I understand the material and not just assume that I know it because the professor made it look easy."

"I would ask more questions in class and visit the professor during office hours."

"I think I'd go back and try to review the final material learned before the exam itself. (Maybe by studying more) I always made time to start studying from the start to the end of the material but never made it to the final topics covered before the exam."

Students revealed that dedicating more time to studying and leveraging office hours are two proactive solutions to improving course outcomes.

V. CONCLUSION

The purpose of this study is to understand whether academic factors, particularly the instructor's pedagogical strategies, or students' external factors are generating the most predicaments in the classroom during a semester span. Based on the responses, there are numerous factors that were identified as significant challenges that affect overall student participation, engagement, and academic success. Balancing multiple responsibilities, academic readiness, and mental and

emotional health issues were all identified as unique factors that students must face while navigating coursework. Many of these students come from working class backgrounds and must carry additional loads to support themselves and/or their families while working towards an engineering degree. For others, the university is a novel environment that is radically different from the K-12 secondary setting. Students may feel intimidated, unsure, or underprepared to traverse the university landscape. As such, it is vital for professors, officials, and staff to help accommodate student needs by offering continuous support and opportunities to connect with institutional resources.

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