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Work-in-Progress: An Analysis of the Effect of Mechanical and Aerospace Engineering Students' Learning Experiences on Career Pathways

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Student Paper
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Introduction

The Mechanical and Aerospace Engineering (MAE) field has a widely documented issue when it comes to retention. Overall, there is a shortage of engineers in industry, and academic institutions face issues retaining students in undergraduate engineering programs. Students are choosing to either switch out of their engineering major or not continue in the field after graduation. To solve this attrition dilemma, engineering education researchers and MAE educators must understand why students leave the field, and what steps can be taken to better retain them. Certain occurrences in students' learning processes could lead to more desirable outcomes, but to learn what these occurrences are, it is necessary to study the holistic learning experience of undergraduate engineering students.

With this review, we aim to gain a larger understanding through literature of how MAE students experience learning engineering. We define engineering student learning experiences to be any experience during students' undergraduate studies that in some way affects their learning of engineering, internalizing and reinforcement of engineering, or applying of engineering. We propose that it would be beneficial to observe learning experiences through three dimensions: professional communities, personal communities, and academic communities. The types of learning experiences captured by professional communities include internships, co-ops, cocurricular activities, interactions with practitioners, and mentorship. The types of learning experiences captured by personal communities include familial interactions, peers, friendships, hobbies, and responsibilities beyond engineering. The types of learning experiences captured by academic communities include institutional culture, design of the program, curriculum, faculty interactions, and advising.

By categorizing the specific experiences of MAE students, we will obtain a new method of observing retention that will inform a larger project examining MAE students' various experiences in their undergraduate programs. Researchers and educators could pay attention to the types of learning experiences discussed in this paper and determine trends that appear in students of varying disciplines and other demographic factors. This paper will also hint at possible connections between the types of learning experiences and various other factors that affect retention, contributing to that larger body of literature.

Review Approach

This paper is a literature review with the primary aim of exploring all types of learning experiences to determine whether they could be captured within the three dimensions of professional communities, personal communities, and academic communities. The literature for this review was gathered starting by searching specific keywords and then branching out through connecting themes from the literature gathered. This allowed us to paint a holistic view of the types of engineering student experiences.

The first keywords consisted of "learning experiences", "aerospace", "mechanical", and "engineering". This combination of search terms did not yield many results as "learning experiences" does not seem to be a widely established term in the literature. In addition to that, the additional restrictions of “aerospace” and “mechanical” further restricted the results. However, some of the literature discovered unveiled the Academic Pathways Study (APS) [1], a multi-institutional, longitudinal study that observed undergraduate student pathways to engineering. The findings from this study contained many of the learning experiences for engineering students and set the groundwork for gathering student experiences. To discover more learning experiences, the search criteria were adjusted slightly to include common factors affecting retention in engineering. Some of these factors include identity, belonging, motivation, difficulty of engineering content, and access to resources. The assemblance of this literature has allowed us to answer two key questions: 1) how have student learning experiences been observed and 2) what are the types of student learning experiences?

We will answer those questions in the remainder of the paper. First, we will discuss two key papers that presented different frameworks to examine student experiences, but neither fully captures all the possible experiences of engineering students. Then, we review papers that reveal, either explicitly or implicitly, the existence of a wider range of student experiences; in the review, we identify and list the various types of student experiences captured in the literature. The papers included here appeared as a result of the literature search or from the literature reservoirs of the authors. We list the various types of student experiences captured in the literature. Following that is a brief comment on the possible effects of the types of student experiences on identity, belonging, motivation, difficulty of engineering, and access to resources. We conclude with a discussion of the current gaps in our knowledge of MAE student learning experiences, and some of the work we plan to do on the topic.

Literature Review

How have student learning experiences been observed?

Two of the selected papers appeared to study the types of student learning experiences; one performed an ethnographic study, proposing a “three dimensional view of engineering learning” [2], and the other is a review of “learning environments” [3] in engineering education.

The goal of the study in [2] most closely aligns with the goal of this review; they argue “for understanding engineering learning with a broader framework” [2] through their framework, “becoming an engineer.” They use person-centered ethnography to determine the context in which the people exist and how they become engineers. They plan to get the whole person’s experience. The framework uses three dimensions through which to view engineering learning: disciplinary knowledge, identification, and navigation. Disciplinary knowledge was most associated with the traditional concept of learning in the school-aged years; identification referred to how a person identifies and is identified as an engineer; navigation focuses on how a person moves through personal and institutional pathways to become an engineer. This work leads away from looking at numbers and percentages of types of students in engineering and toward the quality of their experiences. In a close look at two of the participants, most of the types of learning experiences listed in the next section appear between the two participants.

The next paper, [3], also looked at student learning experiences, particularly those restricted to the curriculum of programs, termed learning environments. It is a review of how institutions are responding to “sustainability, the fourth industrial revolution, and employability” [3] and how they should respond in the future. The emerging learning environments they discuss are student-centered learning, contextual practice, digital learning, and professional competencies [3]. Student-centered learning refers to methods such as active learning, collaborative learning, team-based learning, design-based learning, inquiry-based learning, and project-based learning [3], all of which have shown connections to positive outcomes in students [4], [5], [6] like motivation [3]. Contextual practice includes elements related to work situations like "internships, industry projects, entrepreneurship, and innovation hubs" [3]. They find that this area seems to be under-researched, but they linked it to positive and negative outcomes. Digital learning is using technologies for learning and is a key support for active learning. These are classroom-level methods that enhance student learning outside of using just lectures. The final emerging learning environment noted is professional competencies; this environment seems to depend on the individual student. The student must construct their learning trajectory through collaborating in community activities.

Overall, these two papers show a wide range of student learning experiences, that were supplemented by other literature. [2] looks at specific elements happening within the students' journeys to becoming engineers like how their experiences shape their motivations, and they observe this metric by looking at the lived experience of the students, mostly captured by their navigation dimension. They study the holistic experience of students, but the framework does not allow for the mapping of specific experiences to retention. [3] looks at what competencies and types of problems students need to know and the existing teaching and learning methods that allow them to achieve that. It falls short in discovering the holistic experiences of students.

What are the student learning experiences?

While existing studies, like the two mentioned previously and the remaining in this review, sometimes observe student experiences directly, there is a need for more granular-level investigations into these experiences and how they interact with each other. To begin such an investigation, we first searched through the literature to identify what types of experiences exist in engineering students. We found that the various types of learning experiences could be described by the three dimensions of professional communities, personal communities, and academic communities. This section lists and describes the types of learning experiences identified in the literature, either through direct observation or implied connections, categorizing them according to the thematic dimensions.

In the first dimension, professional communities, the types of experiences are characterized by students having interactions with engineering outside of coursework and the specific institution's program. These types of learning experiences are completely optional for engineering students, meaning that students can navigate their undergraduate studies without having any professional community learning experiences. The types of learning experiences belonging to this dimension are industry and research internships, co-ops, co-curricular activities, interactions with practitioners, and mentorship and they are exhibited in the six papers [2], [3], [7], [8], [9], [10], [11]. Internships and co-op experiences give students hands-on experience with engineering and allow them to apply concepts from their coursework in the field and vice versa [2], [3]. These experiences also give students a break from the extremely competitive environment that exists within MAE programs. Co-curricular activities should fall within the same vein as internships and co-op experiences; these activities allow students to receive hands-on experience with engineering and exist within a community of engineers [2], [3], [7], [8], [12]. Research internships are similar to industry internships, but they generally take place within the academy and MAE department culture. The next type of experience, interactions with practitioners, generally occurs during the previously mentioned types of experiences [2], [3], [9]. Students could also have interactions with practicing engineers through presentations and site visits, allowing them to see the perspectives of engineers and learn more about what the field looks like. Finally is mentorship [2], [9], [10]. Mentorship can come from a faculty member or professional engineer and entails the mentor providing the student with guidance and clarification regarding what MAE is and what the student can expect from the field.

The second dimension, personal communities, characterizes the types of experiences as relating to students' personal lives outside of their studies specifically. These types of experiences relate to work-life balance and support systems around the student. The types of experiences are familial interactions and support, peers within engineering, peers outside engineering, role models, and responsibilities outside engineering coursework and they are exhibited in the five papers [2], [7], [8], [13], [14]. Familial interactions can influence students' decisions to stay in engineering, depending on how much support they may or may not provide either emotionally, intellectually, financially, or otherwise. This type of experience can vary greatly in different communities [2], [7], [8], [13], and can include family, friends, and other people involved in students' personal lives. The next types of experiences have to do with peer interactions. For engineering students, the literature shows that there is a distinct difference between interactions with other engineering students and those outside, manifesting in an "us vs. them" mentality, where engineering students view non-technical major students as "other" [2], [13]. This mentality could even extend across engineering disciplines, causing a greater need to observe experiences within MAE. Engineering peer interactions could occur inside or outside the classroom, like working on group projects, forming study groups, and other general support groups [7], [8]. Role models are similar to mentors, but they are unrelated to engineering, giving the student guidance through life generally, and offering support outside of school [2], [8], [13]. Another important type of experience is the students' responsibilities outside of their engineering coursework [14]. These responsibilities include hobbies, caring for a family, and working a part-time or full-time job.

The third dimension, the disciplinary program, characterizes the types of learning experiences as related to factors controlled by the institution and department that they are located within. These types of experiences are the institutional culture, program design, curriculum, faculty interactions, and advising and they are exhibited in the five papers [2], [8], [10], [13], [15]. The institutional culture refers to the climate within their institutions and departments. Some literature has shown that it's common for engineering students to feel isolated in their studies, feeling that they must tough out the struggle by making social sacrifices to succeed [2], [8], [13], [16] and this is especially true for MAE students as the coursework tends to much tougher. The second type of learning experience, program design, refers to how the engineering department or program is situated within the institution at large. For example, in some institutions, one is admitted directly to the engineering program, for some, there is a soft admission, contingent on one completing their gateway courses, for others, after being admitted to your institution, there is a separate application to be admitted to the engineering program [2]. These different experiences could play a part in introducing additional barriers to students continuing in engineering. The next learning experience, the curriculum, is maybe the biggest experience for students. However, this may be the case due to the curriculum being among the most widely researched topics in engineering education. The content for engineering is generally agreed to be hard [2], [10], [13], [15], [17], [18], and the difficulty can be multiplied by poor instruction, especially in MAE. There are many possible variations to the curriculum of engineering programs that contribute to this type of learning experience: type of instruction (lecture, project-based learning, active learning, cooperative learning, etc.) [19], class order (prerequisites and corequisites), location of courses (within or outside engineering departments), and required courses [2], [8]. The next type of experience is students' general interactions with faculty within the classroom and outside the classroom [2], [8]. The final type of learning experience in the disciplinary program domain is advising [2]. Advising is distinct from mentoring in that an advisor offers the student guidance on how to navigate the program that they are enrolled in, while a mentor shows the student more of what it means to be in the field they are in. Generally, an advisor is provided by the institution while students would have to find and build a relationship with a mentor.

It is important to note that we did identify a few possible limitations for this type of framework. Certain experiences do not fall clearly into specific dimensions. For example, a peer mentoring experience could be classified as personal, professional, or even academic, as the student is interacting with their peer while also sharing a mentor-mentee relationship. Additionally, this framework does not distinguish between leadership or participant roles in an experience. As an example, observe the cases where students are 1) participating in a co-curricular club versus holding a leadership position in that club or 2) participating in a course as a student versus participating as a TA. These are very different interactions with 1) co-curricular activities and 2) the curriculum, but that nuance is not captured by this framework. However, we still argue that its still beneficial to look at MAE student learning experiences through this framework, as it does still closely reflect the holistic experiences of engineering students in general. The dimensions and their learning experiences are shown below in Figure 1.

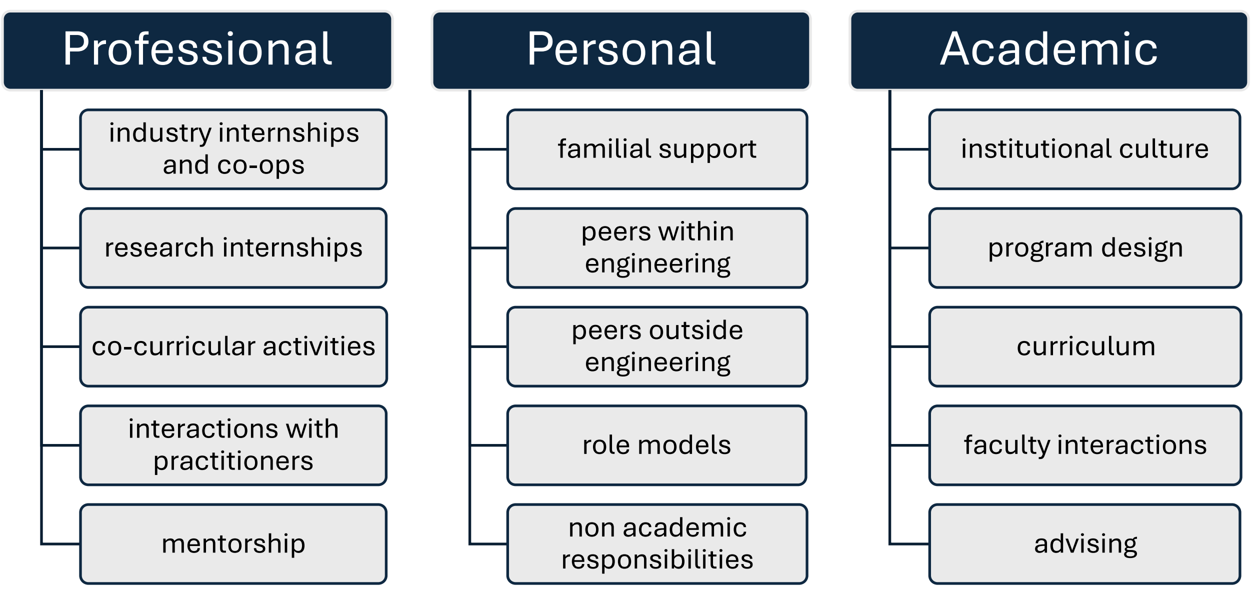

Fig. 1. Proposed dimensions for the analysis of engineering student learning experiences.

Preliminary look at the effect of these types of learning experiences on retention

We've shown that there exists a large wealth of experiences that engineering students can go through during their undergraduate studies. Since the experiences were not explicitly always shown in literature, we observed some connections between the learning experiences and various factors affecting retention in engineering. In this section, we briefly discuss how the learning experiences relate to the pipeline analogy, identity, belonging, motivation, difficulty, information about engineering, and access to resources.

The pipeline analogy relates to the idea that there exist rigid pathways that engineering students flow through to become engineers [2], [9], [10], [13], [20]. Alternative pathways can manifest in engaging in internships or co-ops to stay in engineering with less than optimal grades [2], or interactions with mentors and advisors in engineering as a transfer student [13]. Identity and sense of belonging were shown to connect to types of experiences from all three dimensions of learning experiences: practitioners and faculty can verbally reinforce students [9], [21], solidarity with other engineering student peers [2], [7], [9], [13], [21], identification with family and friends [2], classification by institution [2], and interactions with course content [13]. Motivation was also shown to connect to types of learning experiences from all three dimensions: internships show positive outcomes in understanding future work and applying knowledge [3], accessing study groups and communities to support [7], classroom instruction aligning with student-valued outcomes [21], student-initiated projects [3], and academic success and failure [2], [15]. The difficulty of engineering was shown to connect to personal and academic experiences: study groups reduced perceived difficulty [13], physical and digital resources [10], students felt they had to work too hard [2], and challenging content [10]. Lack of information about engineering has shown connections to professional and academic learning experiences as mentoring or advising can dispel confusion about what students can expect from the field [2], [13]. Access to resources showed connections to all three dimensions: participation in professional organizations gives students access to more resources than students navigating alone [2], expectation to use resources outside class on problems [2], institutional support structures help with financial resources [7], and social networks can help with financial resources [7]. The three dimensions in this proposed framework could lead to broad implications for types of learning experiences on retention and the above factors affecting it.

Discussion

Working toward a holistic understanding of MAE student learning experiences

The overall goal of this review is to work toward a fuller understanding of MAE students' learning experiences. We were able to observe and determine a wide range of types of learning experiences and divide them into three distinct domains: professional communities, personal communities, and academic communities. Professional communities include types of learning experiences where students interact with engineering outside of their engineering coursework and academic program: internships, co-ops, co-curricular activities, interactions with practitioners, and mentorship. Personal communities include the types of experiences related to the personal lives of the students: familial interactions and support, peers within engineering, peers outside engineering, role models, and responsibilities outside engineering coursework. Academic communities include the types of experiences dependent on or mostly controlled by the institution and department: institutional culture, program design, curriculum, faculty interactions, and advising.

Among these dimensions, the most heavily researched is academic communities. Much of engineering education research to date has looked at curriculum and program design, especially when it comes to classroom best practices and how students learn [4], [5], [6], [8],

[22]. Less researched are personal communities as they relate to engineering students and the impact that they have on student learning. By far, the least researched dimension is professional communities and what is the role of these types of experiences when it comes to student learning.

Professional experiences are completely optional for engineering students. They are forced to live through personal and academic experiences, but this is not the case for professional experiences. Additionally, these experiences are not available or known to everyone. Could there be something said about those who have access to such experiences? What about those who don't have access to those types of experiences, but still persist in engineering? These are questions that can be further explored with research focused on the dimension of professional community learning experiences. Researchers could explore the role of key stakeholders in MAE like industry, academic institutions, and government [23] in such experiences, as well as how necessary these experiences are and how they could be supplemented for those who don't have access to such opportunities.

While we've determined the vast spectrum of the types of learning experiences, this review did not yield "how" they appear nor the specific learning experiences unique to MAE students. However, this framework could be a powerful tool in enhancing our future understanding of learning experiences within the field. Across these types of experiences, students can have positive or negative interactions with the experience, or they could not have specific types of experiences at all. More research needs to be done into how these experiences manifest in MAE students, and how they manifest in the different disciplines within engineering. Additionally, with more research, we will be able to identify what combinations appear to be most important when it comes to retaining students in engineering.

Future Work

The future of this study entails a two-part mixed methods study of MAE undergraduate student learning experiences at a large midwestern research-intensive university. The first part will survey the students to determine the extent of their experiences, and the second part will include interviews to further elaborate on how their experiences manifest. This study will shed light on the types of learning experiences shared by MAE students and give more information and knowledge about how these types of learning experiences can affect the retention of MAE students in engineering.

Conclusion

This review exposes a new way to consider and study student learning experiences. The diverse types of learning experiences of engineering students could be categorized into either professional community experiences, personal community experiences, or academic community experiences. Professional community experiences are the least researched and understood dimension of the three, and academic community experiences are the most researched. Focusing research on the specific types of learning experiences could shed light on how to better prepare students for careers in engineering based on their experiences in their undergraduate programs.

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