

A Qualitative Case Study of Persistence of Engineering Undergraduates*

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Recent years have seen a surging need for engineering undergraduates, as many countries have looked to such a group to spur economic growth and compete internationally. However, the retention rate of engineering undergraduates has been a long-standing issue in the United States. Most often, literature provides aggregate results about student retention, but does not describe in sufficient detail how individual students make their decisions to leave or stay in engineering. This paper contains a qualitative case study of persistence of engineering undergraduates by describing the detailed narratives of five study participants who recently dropped out of engineering programs at a large, public research university in the Mountain West region of the USA. Each participant had different family backgrounds and varying experiences within engineering and education. Common themes expressed among the five participants included: a loss of connection and interest in engineering, and experiencing barrier courses that challenged them academically. Participants urged future engineering students to understand the high level of commitment necessary to make it through the academically rigorous undergraduate engineering program before starting.

Keywords: persistence; engineering undergraduates; qualitative case study

1. Background

As engineering plays a more and more important role in the economic growth and international competitiveness of many countries, recent years have seen a growing need to increase the number and quality of engineering undergraduates [1]. However, the retention of engineering undergraduates has been a long-standing problem in the United States [2]. This problem has been highlighted in a number of studies by government agencies, such as the National Academies of Sciences, Engineering, and Medicine [3]. Recently, the American Society of Engineering Education (ASEE) conducted a student retention project [4]. Based on the data ASEE recently collected from many institutions across the USA, it was found that the six-year graduation rates varied between 38% and 67% among different ethnic student groups, and that engineering retention and graduation rates have been a significant concern for decades [4].

To improve engineering retention, it is necessary to understand why students leave engineering [5–8]. Van den Broeck et al. [9] found that students' academic backgrounds significantly affect student retention. Academic background variables investigated included students' level in mathematics, position in mathematics class, overall graduate point average (GPA), and efforts made for study. They concluded that overall GPA plays the most important role in student retention [9].

Jackson et al. [10] studied past, present, and future factors that affect student persistence in engineering. Gender differences were also considered in their study. They concluded that “present factors were more important than past or future factors in distinguishing between engineering persisters and nonpersisters” [10]. Jackson et al. [10] also highlighted the importance of student GPA in predicting student persistence in engineering.

Hall et al. [11] studied the relationships of aptitude and personality traits in predicting the retention of engineering undergraduates. Their study included three groups of students: those persisting in engineering, leaving in good standing, and leaving in poor standing. They concluded that “math skills, especially calculus readiness, were strong predictors of retention” and “high school academic performance and conscientiousness were also significant predictors” [11].

Belser et al. [12] examined the effects of career development factors on undergraduate student retention in science, technology, engineering, and mathematics (STEM) majors. The three career development factors they studied included (1) STEM-focused career planning intervention, (2) students' initial major declarations, and (3) changes in scores on a measure of career readiness. They concluded that all three factors were statistically significant predictors of STEM retention, and that the students' initial major declaration was the most influential variable.

Ortiz and Sriraman [13] conducted an institu-

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tional self-study to examine why students left STEM. Institutional data, an online survey, and a focus-group faculty interview were employed in their study. They found that student retention could be improved by providing support and professional development for STEM instructors, offering supplemental instruction in math and science courses, and providing early internship experiences for students to better prepare them for STEM education.

The results of literature review show that both qualitative and quantitative research has been conducted to study why students leave engineering [5–13]. A variety of factors affecting student persistence and retention in engineering, such as students' academic preparation and readiness, the quality of teaching, as well as the academic and financial support students received, has been studied [5–13]. However, most often, the majority of literature provides only aggregate results about student retention, with no sufficient detail of how individual students made their decisions to leave or stay in engineering. A description of students' detailed stories, rather than aggregate results, is especially helpful for developing a better understanding of students' decision-making processes. The present study fills this research gap by providing detailed narratives of five students who recently dropped out engineering programs in their undergraduate study. The five students were from the authors' institution, a large, public research university in the Mountain West region of the USA. Many undergraduates at the authors' institution take a two-year leave of absence during their undergraduate study for religious missionary services outside the institution.

In the remaining sections of this paper, the methods of research and data collection are described, followed by a description of five students' detailed stories. Discussions are made. The limitation of the present study is described, and conclusions are made at the end of the paper.

2. Research method and data collection

2.1 Research question and method

The research question of the present study is: Why did the five students involved in the present study leave engineering? The research method used in the present study is qualitative case study, a method of qualitative research that aims for “exploring and understanding the meaning individuals and or groups ascribe to a social or human problem [14]”. Qualitative case study is “a design of inquiry . . . in which the researcher develops an in-depth analysis of a case, often a program, event, activity, process, or one or more individuals [14]”. The sample size in case study is typically small, such as only a few

participants, to enable in-depth investigations with each participant. Common methods used in qualitative case study include individual interviews, focus group interviews, open-ended questionnaire surveys, and behavior observations of participants. In the present study, individual interviews were conducted.

2.2 Data collection

The research site of the present study was at a large, public research university in the Mountain West region of the USA. The university has a College of Engineering, which offers six undergraduate engineering programs: biological, civil, computer, electrical, environmental, and mechanical engineering. To recruit student participants (hereafter referred to as “participants”), emails were sent to a list of undergraduates who had recently dropped out of the engineering program. Those who responded to the emails were subsequently invited to face-to-face interviews.

Prior to the interviews, participants were provided an example journey map from Nyquist et al. [15], so they learned how to draw their own journey maps. They were asked to bring their own journey maps to the interviews. Journey maps helped participants describe their experiences with engineering programs and were employed as a useful guide for their stories into and out of engineering. It was found that journey maps were very helpful to keep participants on target throughout the interviews.

Five participants were involved in this qualitative case study. These five students were recruited using the method described before. Pseudonyms—Abe, Bill, Charles, Jim, and Scott—were used in this paper to protect the identities of participants. Prior to the interviews, all participants signed on the Letter of Informed Consent approved by the university's Institutional Review Board. The following paragraphs list some questions employed in the semi-structured interviews:

- What factors led you to leave engineering?
- How did your pre-university experience prepare you for the engineering program?
- If you could go back and change anything, what would you do differently?
- What would you suggest to future engineering undergraduates to increase retention?
- What changes would you suggest the engineering program make to increase retention?

The interviews were audio-recorded and transcribed. Data analysis was made based on the transcriptions and reflections from the interviews as well as the graphic journey maps that participants had generated.

3. Results

3.1 Story of Abe: "engineering is not for me"

In his third semester of the mechanical engineering program, Abe realized that engineering was not the path for him. He explained, "My dad and three of my four brothers are engineers. I always planned on it [becoming an engineer], but I just didn't fit." With excellent grades in high school and an aptitude for math and science, Abe attended a pre-college engineering workshop during the summer between his junior and senior years. He remarked, "I loved the mechanical aspect of engineering. We worked on robots there [at the precollege engineering workshop] and I thought it was cool that a bunch of people could work together on a project that could really do something." Abe's father urged him to become an electrical engineer. Abe's mother, "thought I should do something other than engineering." Abe settled on mechanical engineering as, "a compromise for my mom and my dad."

As can be seen on his journey map (Fig. 1), as Abe was considering what to do with his life, the influences of his father and brothers, as well as his love for math, were strong factors in his choice of major. Abe enrolled in the pre-professional mechanical engineering program in the fall semester. Abe participated in the honors program at the university and had access to, "the honors program advisor. I never met the advisors in the engineering college. My

advisor was an older guy and was very helpful. He came up with a pretty aggressive 4-year plan."

Abe's first semester was full of "challenging" classes, but as Abe explained, "I had my brothers to help me. They had just gone through it, so school was pretty easy for me." Having passed the calculus AP test in high school, Abe was qualified to take Calculus II his first semester. He did well and earned an A grade. He said, "I never even thought about using the tutors. I had my brothers and they were probably better than the tutors anyway."

Abe had a manufacturing processing course in his second semester. Although he enjoyed the course and had a "really good teacher," Abe "got my first B ever." He explained, "The course really challenged me and sort of scared me. I had never been challenged academically before. I wasn't as prepared as the other kids [his classmates] for the class. I thought maybe engineering wasn't for me. I also had an elective class in the same semester. I think it was called 'philosophy and ethics.' I loved it and started thinking about doing that instead [of engineering]."

That philosophy and ethics class was, "the first elective class I think I had ever taken in my life," Abe noted. Abe spoke with his father about getting out of engineering and finding a career in philosophy. Abe expressed, "My dad was not open to the idea. He told me you can't make money in philosophy." As depicted on Fig. 1, Abe was very conflicted on his academic future.

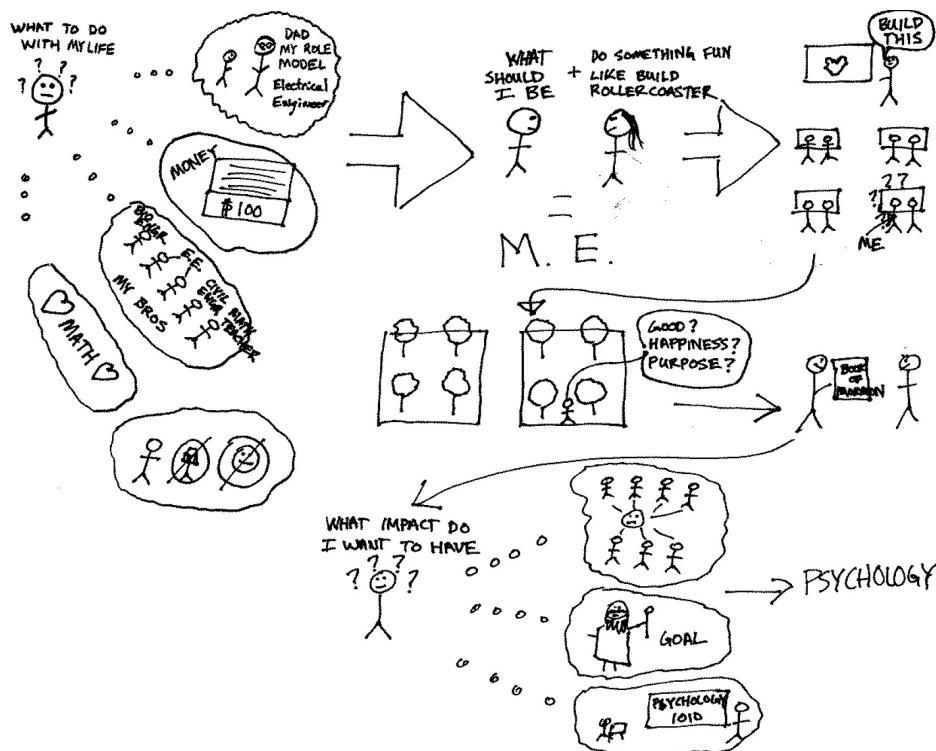


Fig. 1. Abe's journey map.

Abe took a two-year leave from school to serve an ecclesiastical mission for his church. During this service, he contemplated his future as an engineering student. "I wanted to serve people with my career. I know engineers provide a great service for people as far as physical things go. I started to think I might want to help with people's emotional burdens instead of their physical burdens," he said. After the religious service, Abe started back in school in the fall semester. He explained, "I went to see my honors counselor when I got back. I explained to him that I had decided to switch majors to psychology. He helped me pick the classes and get signed up."

Abe went into the engineering administration office to let them know that he was transferring out. "When I signed that paper [form indicating that he was transferring out of engineering], I felt this rush of relief. I was a little confused and unsure, and I felt like I was starting over again, but I was still relieved," he said. When asked how his family responded to his decision, Abe responded, "My brothers supported my decision. One of them said it was about time I did something different. My mom was glad that I was doing what I felt was right for me. My dad was skeptical . . . he still is . . . about my decision. I feel like I did the right thing."

When asked what advice he had for future engineering students, Abe said, "They really need to examine their motivation for wanting to be an engineer. They need to ask themselves what kind of

benefit they want to bring to the world." His advice to the engineering college to increase retention was to "help students understand how intense and overwhelming engineering can be" and "helping engineering students to be comfortable seeking help. It is hard to switch from getting good grades to getting bad grades."

3.2 Story of Bill: "I just did not have time and money"

Figure 2 is Bill's journey map showing his experience with engineering and education. He explained, "I think I was always mechanically inclined. I tinkered with everything that moved when I was growing up." In his forties, Bill had "a long road" before enrolling in engineering. "I liked mechanical things, and I always felt drawn to working on cars and bikes. My dad died when I was in high school, but before he died he told me he really wanted me to graduate from college and become an engineer. So I started getting things in shape to do that." As depicted on Fig. 2, Bill became a mechanic for a few years. "It was still my goal to become an engineer, but life sort of got in the way for a while," he explained.

Bill began taking some drafting courses to prepare himself for engineering school. He received good grades in these courses and felt like drafting "came naturally" to him. Bill's first semester as an engineering undergraduate student was "fun and really pretty easy." He got good grades and was very

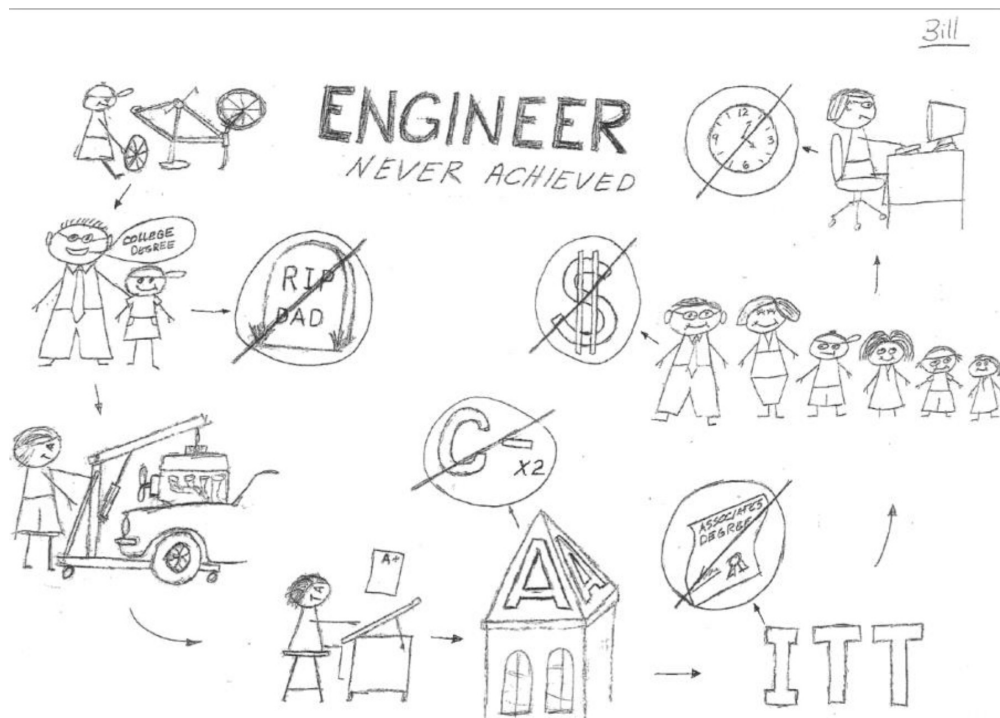


Fig. 2. Bill's journey map.

interested in the material. He had chosen civil engineering based on his experience with drafting courses. "It felt like a perfect fit for me," he said.

Bill began taking, but struggled in, his math courses in his second semester. "Before I knew it I had two C-'s on my record and I had a whole bunch of math classes left," he explained. Bill considered dropping out of engineering. As he said, "I didn't feel like I had much of foundation in Calculus I, and I had a bunch of stuff going on at home. I think I could have done it [passed the math courses] if I could have focused just on that. But at that time in my life it was just impossible. I talked to the advisors, but I already knew what the problem was. I just didn't have time." Dealing with pressure from "two fronts," Bill decided to drop out of the engineering program. "I just didn't have the time or money," he said.

Bill decided to attend a technical drafting school to increase his income and put himself in a position to return to engineering. "Then the family grew and the debt increased," he explained. He obtained a computer-aided designer position that he turned into a career. When asked about his emotional experience leaving engineering, Bill replied, "It was hard. I do feel like I let some people down. I had to be realistic though. The position I was in just wouldn't work. I feel like I do civil engineering without the stamp. It bugs me that an engineering

license is not an option for me without starting over completely."

Bill suggested to the future engineering students that "Make sure you really have the time and the resources to do it [complete engineering college]. It takes a lot more time and effort and commitment than you might think. Don't let small things frustrate you to the point that you want to quit. Don't let a five minute conversation with an advisor change your life. You have to have a thick skin to make it through."

3.3 Story of Charles: "I wanted to be a teacher"

"Basically forever I have always enjoyed math and science," said Charles when he was asked about his original draw to engineering. His father is an electrical engineer, two brothers are physicists, and another brother is a math teacher. Charles had been around math and science his whole life. Originally, Charles felt his calling was to be a teacher, as illustrated on his journey map (Fig. 3). Feedback from family and friends discouraged him from teaching because "teachers don't make much money." Between his junior and senior years of high school, Charles attended a summer program that was intended to inform high school students of some of the opportunities available for engineering students. Charles thought the program was very fun, and he was convinced to enroll in the engineer-

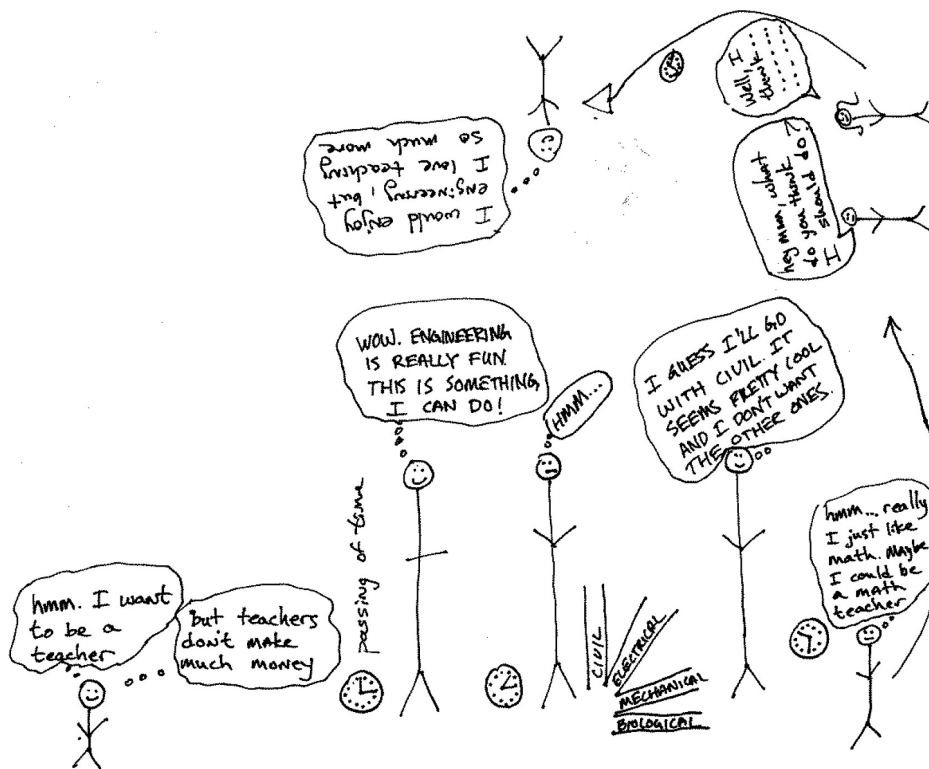


Fig. 3. Charles' journey map.

ing college. He had not decided which branch of engineering to pursue, so he majored in general engineering.

“I was planning on going on a mission [a two-year Church service mission] after the first year of school, so I thought I would just wait to decide [on a major] when I got back.” Charles relayed an experience talking to his roommate about picking an engineering major. He said, “My roommate found a list of things each type of engineer did. I listened to all of them and, although I thought some of them sounded fun, there wasn’t anything I really felt passionate about.”

Charles took a two-year leave of absence from school for Church service. When he came back to school he had still not decided which, if any, engineering major to pursue. “I kept procrastinating my decision,” he explained. He enrolled in general education classes including psychology and philosophy. He enjoyed the psychology course and termed psychology his, “. . . mistress major. I really like it but I won’t ever commit to it.” He decided he would pick an engineering major and start a full course load the following semester.

He met with the engineering advisors who he found “very helpful”, and decided on civil engineering. “The counselor helped me put together a basic plan that showed I had three years left . . . so, four and one half years total,” he said. Charles signed up for several core civil engineering classes including computer programming. A few days later, he with-

drew from all but one course and changed his major to math education. He said, “I am not a computer guy. With my background I didn’t really have trouble with classes, but computer programming was hard. I withdrew before a W would show up on my transcript. I had four days to pick a new major. Since I always loved math and I wanted to be a teacher, I chose math education.”

Charles set up an appointment with an advisor from the math department. He also spoke with his mother, an elementary school teacher, to get her opinion. He said, “My mom was very supportive and excited [about my switch to math education]. She said I had a great personality to be a teacher.” Although Charles did have some regrets about leaving engineering, he said, “I pictured myself in the future as an engineer, and I think I would have regretted not being a teacher.”

Charles’ advice to the engineering college was to, “explain to the [summer engineering introductory course] people that engineering is fun but really hard. I would have really enjoyed a class that explained the different kind of engineers . . . it would have helped me stay [in engineering] or make the decision [to switch out of engineering] sooner. To future students, his only advice was, “If you like it, go for it.”

3.4 Story of Jim: “[I] wasn’t really sure what exactly computer engineers did”

Jim thought his home school background left him,

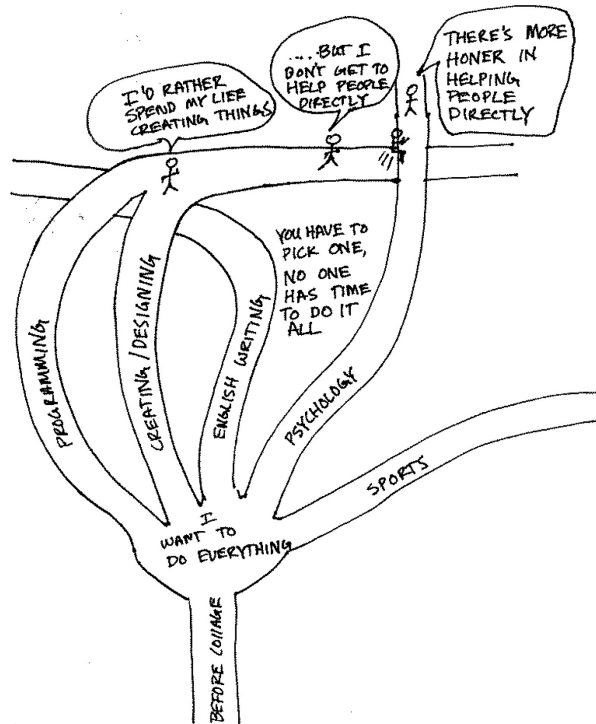


Fig. 4. Jim’s journey map.

in some ways, unprepared for the decisions he was compelled to make in college. He explained, “I skipped middle school and my high school was more like a correspondence course, so I didn’t have too much social interaction.” Jim had given “no thought to engineering” until it was time for him to pick a major. He said, “I felt like I really wanted to do everything. But, I know I can’t do that so I chose computer engineering because I like video games and programming.”

Jim’s journey map (Fig. 4) illustrates several options he chose from in picking a major. He saw computer engineering as a way to, “. . . change others’ ideas and make them better.” Jim admitted, however, that he wasn’t really sure what exactly computer engineers did when he chose this field of study. Jim enrolled in computer engineering, but had several math courses to make up since he came to college without any AP or college credit classes. “I started Math 1010 [an introductory level math class] and I was doing homework in that class alone for up to six hours per day,” he said. Still feeling “disoriented” in his new college environment, Jim began to understand the level of commitment required to be an engineer. He earned a C- in Math 1010 that “scared” him a little. Still, he remained excited about the prospect of becoming a computer engineer.

The following semester, Jim tackled trigonometry and college algebra. He earned a C in trigonometry and a B in college algebra. Jim felt he was doing better in math, and he had made more friends at the university and within the engineering college. “I was feeling better about engineering and my chances of making it, plus I wanted to be around people more,” he said. Jim stayed at the university and worked over the summer. He found time to participate in “extreme” outdoor activities with his friends. He worried about the time commitment he would have to make to pass his upcoming math courses.

The following semester he enrolled in calculus I. As he said, “I spent three fourths of my overall homework time on that one class and still got an F” and “I’m confident that if I took it [calculus I] again, I could pass now that I know how it works . . . I asked myself who I am going to become if I did it [retook the course]. I knew I would become more isolated.” Jim passed all of the rest of his classes that semester and determined that he was going to “find something else to study.”

Jim took the next semester off because he “had no money and didn’t know what to do.” He explained, “I could justify getting some student loans if I knew what major they were going towards, but I didn’t.” Fearing the isolation Jim perceived that came with computer engineering, he decided that psychology

would be a good way to “get involved with people more.” He transferred to psychology and expects to graduate in another two years.

When asked what advice he would have to future engineering students, Jim said, “Once you decide to do it [study engineering] jump on it ASAP.” He also recommended that students do the math series “somewhere else like a smaller college.” Finally, he mentioned that there is a lot of information students can access for free to get them ready for the overall college experience.

3.5 *Story of Scott: “I was stressed all of the time”*

With a solid background in math and science and two brothers who had recently completed engineering programs, Scott felt that he was well prepared to succeed in engineering. He had taken advance placement courses in high school for math and history, and had passed the tests. He explained, “Even though I passed AP [advance placement] calculus in high school, I knew that it was math that killed everybody in college, so I took [Math] 1050 [an introductory math course for the engineering programs] at the community college.” He described having had a great experience with math at the community college. Scott earned “A’s and B’s” in high school and described himself as a “good student.”

On advice from his brothers, Scott “paced himself” on the course load he took his first few semesters in the engineering college. “My brothers both struggled to make it through engineering, so they told me to take it slow at least at first,” he said. Scott’s first semester included Calculus II where he earned a D. He explained, “The material was just tough. I think the teacher was ok. It scared me to get a D. I had never gotten a failing grade before.” Scott retook, and passed Calculus II in the following semester. Although he enjoyed the rest of his schedule, Scott was, “. . . scared by the math. I don’t know if it was the teaching style or my learning style, but I just couldn’t get the material fast enough.” Scott’s older brother spoke with him about his diagnosed Attention-Deficit/Hyperactivity Disorder (ADHD) and suggested that Scott should visit a doctor to figure out if he had the same condition. Scott said, “When I told my brother the trouble I was having understanding the material, he told me that he had the exact same problems when he was in my position. He said getting treated for ADHD really helped him.”

Figure 5 is the journey map Scott prepared to illustrate his experience with engineering. The drawings and formulas on the left indicate Scott’s perceived experience with math at the beginning of his university experience. Scott found a job on campus that allowed him to get some “hands on” experience

commitment necessary to make it through the academically rigorous engineering program.

Second, during the interviews, participants all mentioned a barrier course that triggered their decisions to leave engineering. This barrier course was like the last straw that broke the camel's back. For Abe, the barrier course was a manufacturing processing course. For Bill, Calculus I. For Charles, computer programming. For Jim: Calculus I. For Scott: Calculus III.

Note that out of these five participants, three mentioned calculus, a math course "that killed everyone in college [quote by Scott]". This research finding is not unusual and surprising. In fact, it is consistent with similar research findings made by other researchers [16–18]. Tyson [18] proposed a model for engineering degree attainment that takes into account student achievements in mathematics courses, i.e., Calculus I, II, and III. Based on the statistical data he collected, he found that "students who earned an A in Calculus II and low achievers in Calculus III were most likely to migrate into business," and "students who earned an A or C in Calculus II also were likely to switch out into computer science" [18].

As Forsman et al. [19] pointed out, student retention is a complex system. It involves numerous influential factors in all three aspects of education: teaching, learning, and the environment to support teaching and learning. Effective educational interventions need to be developed or adopted to improve student performance and thus to improve engineering retention [20]. Although a detailed discussion about these interventions is beyond the scope of this particular paper, it is worth mentioning several interventions that are based on active learning methods [21, 22] and technology-enabled assessment methods [23, 24]. Representative examples of active learning include collaborative learning [25, 26], project-based learning [27, 28], problem-based learning [29, 30], and flipped classrooms [31]. Research evidence has shown that student performance can be improved if these active learning methods are adopted inside and outside the engineering classroom.

The primary limitation of the present qualitative study is that all participants were from the authors' institution at which many undergraduate students take a two-year leave of absence for religious missionary services outside the institution during their undergraduate study. The leave of absence occurred during either the first or the second year of their undergraduate study. Although there is no systematic study on how the two-year, mid-way leave of absence affects student retention, it is obvious that after students came back to school, some had to relearn the course materials that they might have

forgotten. If students perform poorly in some courses, they might change their minds and decide to leave engineering. In addition, all participants involved in the present study were white males. Research has shown that female and racial minority students also have their own reasons to leave engineering [32, 33]. The lack of engineering identity and communication networks is often reported as one of the major reasons that female and racial minority students leave engineering. Therefore, the opinions expressed by the five participants at the authors' institution might not be representative among different institutions across the country.

5. Conclusions

Engineering retention has been a long-standing issue in the United States. This paper has described the results of a qualitative case study that involved the semi-structured interviews of five participants who recently dropped out engineering at a large, public research university in the Mountain West region of the U.S. Participants generated journey maps and described their stories on why they left engineering programs.

Each participant is unique in terms of their family backgrounds and experiences with engineering and education. Based on the analysis of the transcriptions and reflections from interviews, as well as the graphical journey maps that participants generated, it was found that each participant had different reasons for leaving engineering. The reasons involve a loss of connection and interest in engineering, as well as poor performance in engineering and mathematical courses. Out of five participants interviewed, three mentioned calculus, a math course "that killed everyone in college [quote by a participant Scott]." Although this assertion made by the student might be exaggerated, it does highlight the extreme importance of students' math skills in engineering retention. Effective educational interventions need to be developed or adopted in order to close gaps between student academic performance and engineering retention.

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