

Migrator Stories in an Aerospace Engineering Program

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Abstract

Aerospace engineering (AE) enrollment and graduation trends over the past decade have not kept up with those of other engineering disciplines even though recent reports predict AE industry expansion and growth. The purpose of this study is to understand why students migrate out of AE to other STEM majors. Students from a large Midwestern university in the U.S. narrated their institutional experiences during their time in the major and their reasons leading to the decision to migrate to other STEM majors. The qualitative data along with schematic descriptions from the interviews were studied through the lens of Tinto's model of institutional departure. Qualitative analysis reveal that students migrate to other engineering majors because their interest in AE dwindled primarily because it constrained their career options or that getting a job in AE industry is very difficult due to the low number of jobs available. The latter sentiment, while untrue, is being fueled by the misrepresentation of the AE industry and efforts are needed to counter this sentiment to keep students motivated to pursue a career in AE.

Keywords: persistence, aerospace engineering, undergraduate, career choice

Problem Definition and Literature Review

The Dire Requirement of AE Graduates in the Workforce

Numerous government and university level initiatives have increased the enrollment and graduation in engineering over the past decade. These initiatives were spurred by low persistence in undergraduate engineering, addressing the gender gap in the workforce and undergraduate engineering, and the requirement of engineers for maintaining the status of U.S. as a leader [1, 2]. While these initiatives have increased the overall enrollment and graduates in engineering (figure 1 and figure 2), including the percentage of women graduates (figure 3), there is a shortage of engineering graduates required only in certain industries where foreign nationals cannot be hired and require a security clearance [3]. One such industry facing imminent shortage of graduates in its workforce is aerospace engineering (AE).

The U.S. Department of Labor Statistics (2019) estimates the employment growth of AE at 7 % for the next decade which is at par with other occupations. The growth in the sector is primarily based on high-end technology jobs such as computational fluid dynamics testing and redesigning aircrafts for better efficiency. Predicting employment growth tends to be conservative. For example, the predicted employment numbers in AE for 2014 was 31,000 but 55,000 were hired [5]. The global AE industry growth is being led by the U.S. with the recent political administration increasing its funding due to the recent increase in geopolitical risks and to establish dominance in space [6]. Asian countries (i.e. China, India, Japan), European countries (i.e. U.K. and France), and the Middle East are expected to increase their funding and global competitiveness in the industry. The increase in funding and the growing interest in the industry is only going to fuel the requirements further. The AE workforce faces a gender gap which is higher than other engineering fields. To elaborate, in 2016, the AE workforce consisted of 12.5 % women in contrast to 20.7% women in chemical and 13.4% women in civil engineering [7]. In addition to the gender gap, 38% of the U.S. AE workforce

is aged 50 or above, which is higher than the mechanical (32%), civil (32%), and chemical (30%) engineering workforces. Considering the gender and age disparity in the AE workforce there is an immediate requirement for new employees who are certified in high-end technology skills usually obtained through a college degree.

One way to address this shortage of workers is to recruit and retain engineering undergraduates who are interested in the industry and actively pursue an undergraduate major towards it i.e. aerospace engineering. Historically, engineering enrollment in the U.S. increased from 1970 through to 1983 where it peaked and then fell steadily till the mid-nineties. In contrast, AE enrollment grew till 1988 and then sharply declined. The reason for this disparity is that while engineering went through downsizing and mergers, 1980's was a dynamic time for aerospace engineering [8]. Truly the eighties were an exciting time for AE industry where the U.S. increased its funding in the sector to almost excessive [9]. Following this period of excessive spending, the sector faced huge downsizing due to the slash in funding and recession. To put it in perspective, the AE sector slashed half a million jobs from 1989 to 1995 [9]. Undergraduate enrollment in AE followed similar trends to that of its industry. Fletcher (1998) warned that the sharp decline in enrollment in AE will have serious consequences on the future of the industry's workforce.

AE Enrollment and Graduation Trends

While other engineering major graduates get hired in the AE workforce, it has not been enough to fill the shortage of graduates required as shown by the lowest women population (12.5%) and highest retirement eligible population (38%) in AE workforce compared to other engineering workforces. To make matters worse for the AE workforce, students who start in AE are most likely not to graduate at all within six years [10]. Graduation rates among AE were found to be lower than the aggregate rates of other engineering majors and were even worse for women and minoritized people races. Students who started in AE and graduated in other majors were equally likely to graduate in a non-engineering major. Another study [11] showed that AE lagged all other engineering majors in first-year and sophomore persistence across gender. The study found AE first-year male/female persistence at 50/46 % in contrast to 73/87%, 68/ 77%, and 82/93% for mechanical, chemical, and civil engineering respectively. AE sophomore male/female persistence were at 76/73 % in contrast to 88/91%, 87/ 91%, and 97/93% for mechanical, chemical, and civil engineering respectively.

Lacking sources to provide the latest numbers on U.S. AE enrollment and graduation, ASEE data [12] provides a good sample to estimate national trends [11]. Over the past decade the mean engineering graduates and AE graduates has increased but the percentage change in the enrollment for AE lags those of engineering in every year except 2014 and 2016 (figure 1). The mean was calculated as a ratio of number of students enrolled to number of universities since the number of universities reporting data to ASEE varied. Percentage change was calculated based on increased mean enrollment since previous year. A positive percentage change indicates increase in mean enrollment/graduation from previous year and vice versa. If the percentage change for a year is higher than its previous year it indicates that the mean increase in enrollment/graduation was higher than the mean increase for the previous year and vice versa. Further investigation reveals that the rate of increase in graduation from previous year for AE compared to engineering lags in every year with the gap showing increasing trends from 2013 onwards (figure 2). To aggravate the situation further, the

percentage of women graduates in engineering have steadily increased over the past decade (more than 3 %) but has remained effectively same for AE (at 14%) which is lower than that of engineering. The trends give an important insight into how minorities are affected in AE. The initiatives by government and universities have increased the percentage of women graduates in engineering but not in AE. The trends for AE fall behind those of engineering at every measure discussed above. The discussion while quantitative in nature reveals that while institutional and governmental actions are working for engineering programs, AE programs and students around the U.S. are facing additional challenges. The only trend in favor of AE that is revealed from the small amount of literature present specific to AE, is that 30 % of AE graduates started in a different major or institution [10]. This implies that AE major becomes attractive after the early years into college when students may have had exposure to internships, research, mentor or faculty, and have had some credible experience with engineering to decide on a major. Lowest persistence rates among all engineering disciplines especially in the early years could also imply that students who start in AE are being pushed out by their early years into an AE program. The options available to students leaving AE are pursuing another engineering major or a non-engineering major.

Migrators

A great deal of research has been conducted on why students drop out of engineering but there is little literature on why students migrate to other engineering majors [13]. Seymour and Hewitt (1997) considered persistence in the context of engineering majors on 460 STEM students from multiple institutions.

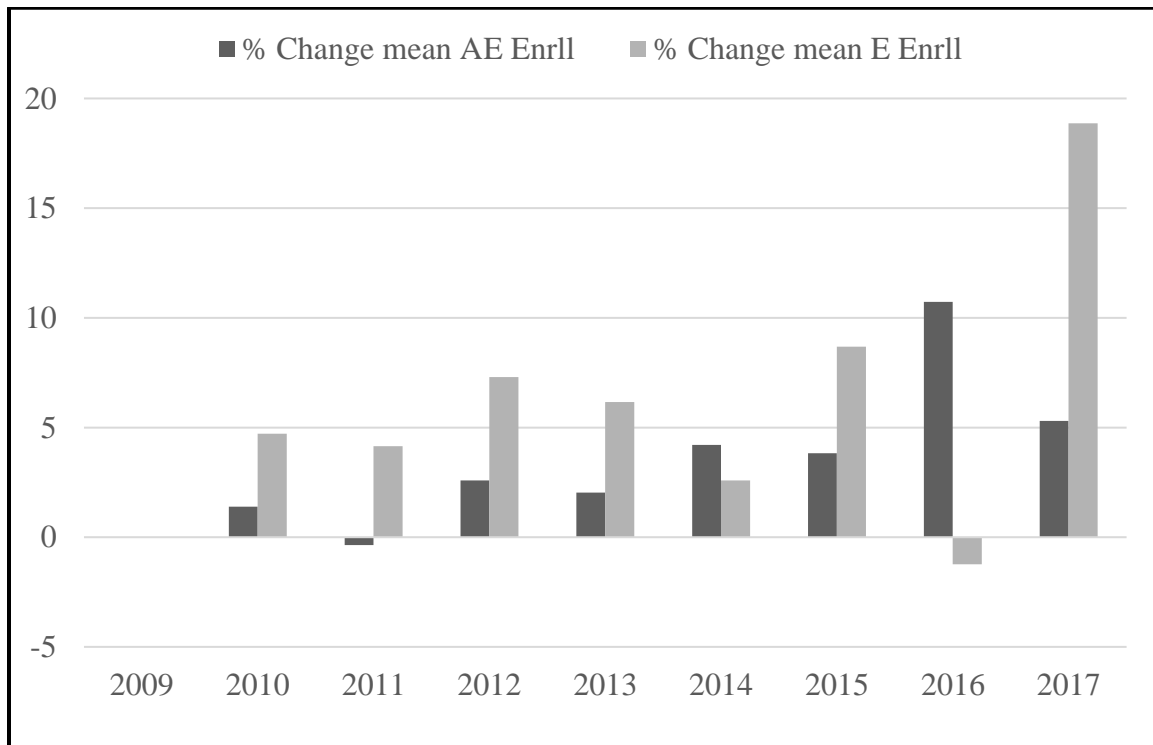


Figure 1 Data on % change in mean enrollment compiled from *Engineering by the Numbers*, ASEE (2008-2017)

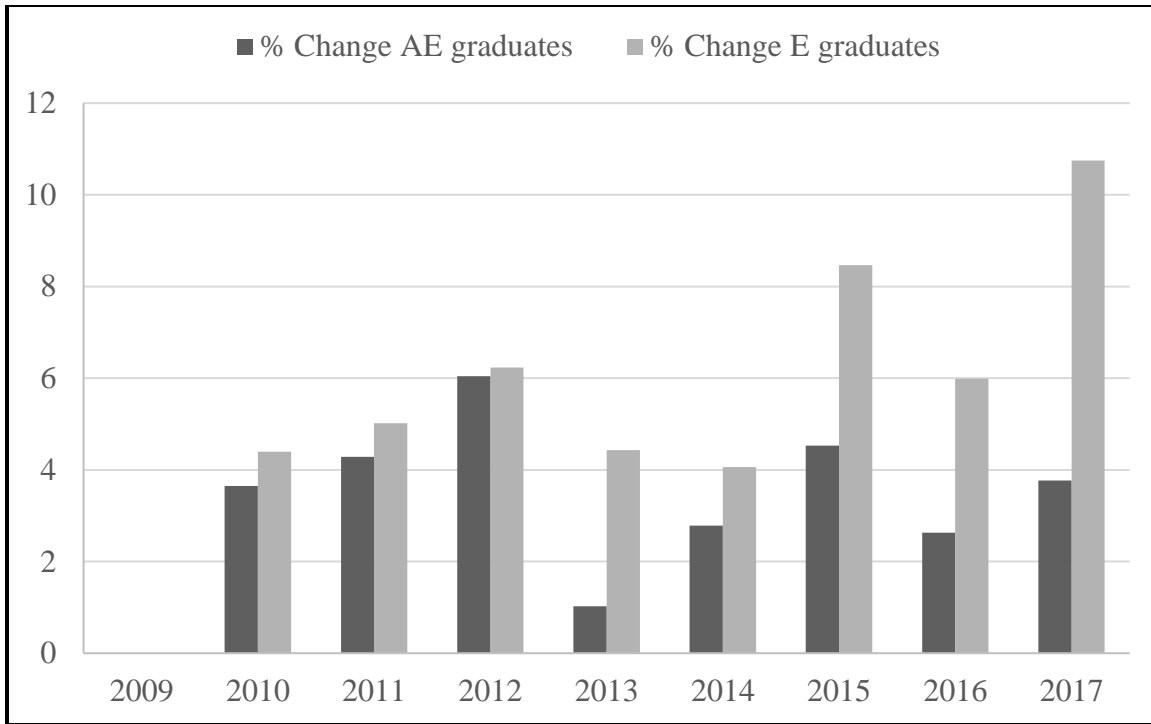


Figure 2 Data on % change in mean graduates compiled from *Engineering by the Numbers*, ASEE (2008-2017)

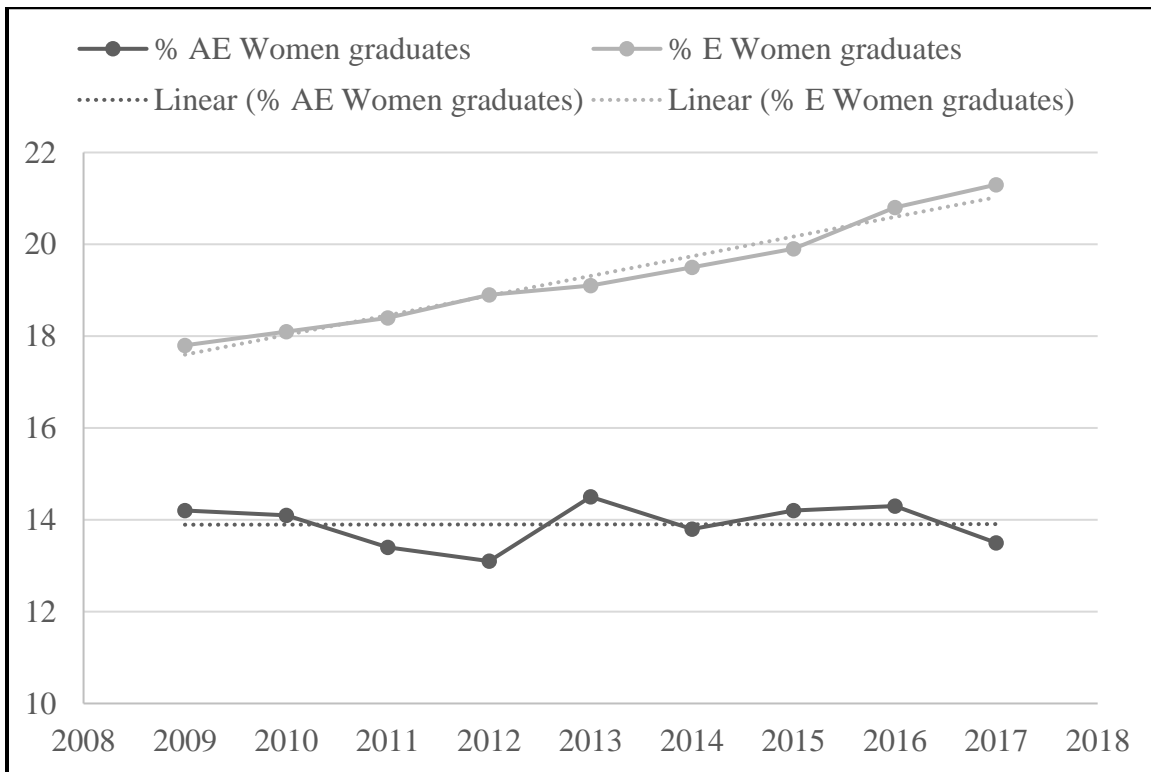


Figure 3 Data on % women graduates compiled from *Engineering by the Numbers*, ASEE (2008-2017)

Students migrating to other STEM majors (migrators) were not less qualified than their peers who persisted in the major (persisters) but had unsatisfactory experiences with teaching and/or perceived lack of success in the major [14]. They found that migrators faced the same problems as students who dropped out of STEM majors (leavers) but chose another STEM major. A qualitative study [15] on students migrating to industrial engineering (IE) showed that students left their initial engineering major because of negative experiences with faculty and classes, very low interaction with faculty, and change in career goals to an industrial engineer. The other studies which have researched migrators are quantitative [10, 13] and describe metrics such as major stickiness (percentage of students that enroll and subsequently graduate in a major) and odds of graduation in the major. Quantitative studies into why students drop a major cannot provide the rich description obtained from a qualitative study that is required to explain student reasoning to leave the major [16, 17], and to inform recruitment and retention strategies [15]. The studies concluded [18, 19] that students' decision to pursue a major and career in engineering can be marketed to students and that research into how institutional factors affect this career decision making could prove valuable. A study [20] on mechanical engineering (ME) student graduation rates showed that almost half of the students who graduated in ME migrated to the major and concluded that ME should serve as a model for other engineering disciplines to adopt to attract students. Most literature in engineering education has treated persisters and leavers as a coin flip and discussion related to migrators has largely remained a gap in literature. Due to the limited literature available on migrators and the similarity in their experiences with leavers and persisters [14], the factors that lead to STEM attrition highlighted by the reports [1, 2] are discussed.

To understand why students drop out of AE we will use the framework described by Tinto (1993). According to Tinto (1993), the decision to drop out is influenced by student Goals and Commitments (post) which have evolved from how well they have integrated academically and socially at the university (Integration). This Integration into the university occurs from the various Institutional Experiences a student has in the Academic and Social systems. The initial decision to pursue a degree is made from the influence of Pre-Entry Attributes on Goals and Commitments (Pre) prior to joining the university. Goals and Commitments lead students to choose AE and subsequently drop it. While Tinto (1993) developed this framework for students dropping out of college, it has been widely used as a framework to understand why students leave STEM (e.g. 16, 17). Due to the similarities with leavers/persisters we used the framework to understand migrators. Understanding this aspect of the framework and how it evolves will lead to a better understanding to why students migrate to other STEM majors.

The report by U.S. Department of Education (2014) highlight Pre-Entry attributes such as family background (women, minoritized people, first generation individual, low income background) influencing students' decision to drop out of STEM majors. Students with weaker academic backgrounds were at higher risk of leaving STEM majors. This directly points to a student's schooling, and skills and abilities prior to joining the institution. Intentions, goals, and commitments were identified as attitudinal factors (motivation, confidence, and self-efficacy to STEM) in the report. Formal academic experiences such as low academic performance and rigor involved with introductory STEM courses lead students to drop out while informal academic experiences such inadequate advising, negative

experiences with faculty were cited as reasons for the same. The report did not highlight any experiences in the social system as defined by the framework.

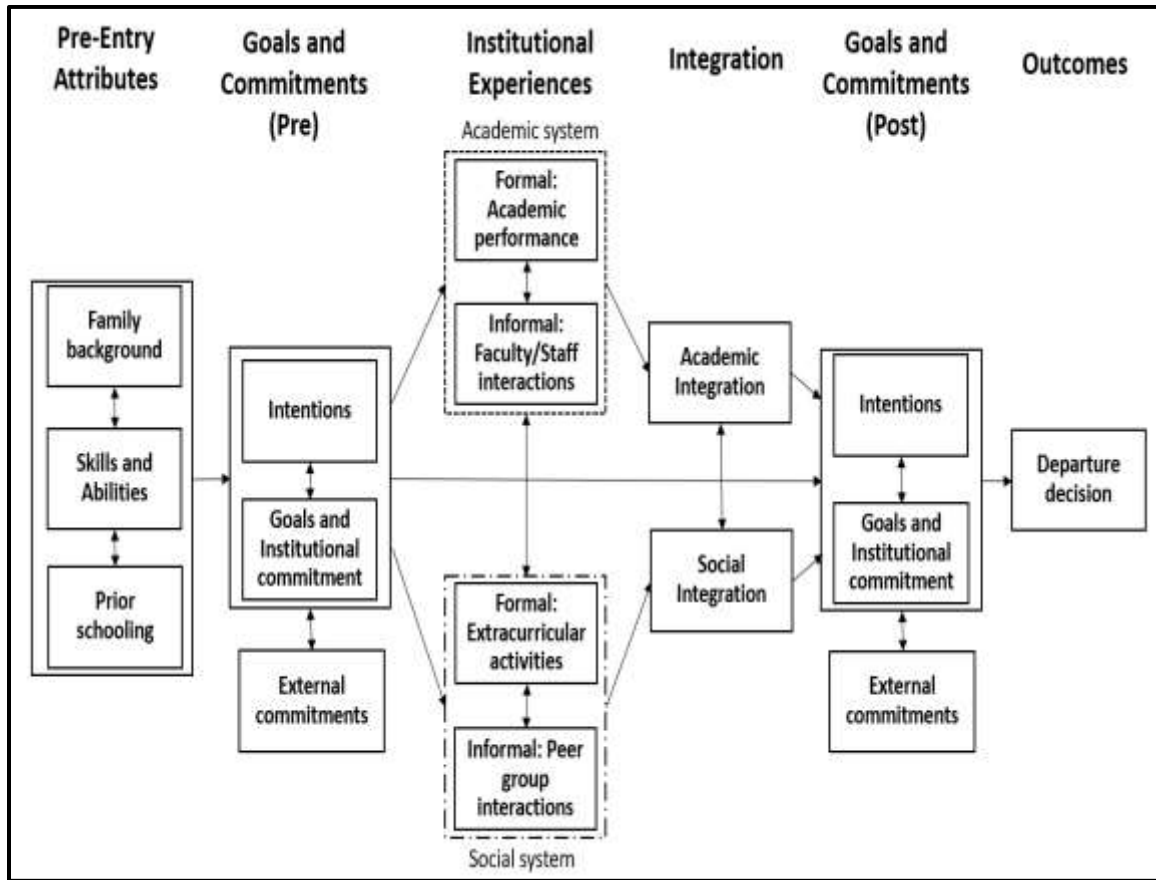


Figure 4 *Tinto's model for institutional departure. Adapted from Leaving college: Rethinking the causes and cures of student attrition 2nd Edition (p. 114), by V. Tinto, 1993, Chicago: University of Chicago Press.*

The report to the President [1] cites lack of encouragement from family and financial concerns (family background) as reasons for STEM attrition. Under the formal academic system, the use of active and problem-based learning in teaching introductory STEM courses were highlighted to increase persistence. This enhanced student attitudes towards STEM and negative performance in these courses discourages students from pursuing STEM major. Informal academic experiences such as faculty interaction through research/laboratory experiences, peer interactions, and study groups help increase persistence in STEM. The evolving Goals and Commitments were highlighted as keeping students motivated towards STEM through role models and increasing self-efficacy in STEM for women and minorities through simple exercises such as writing about their values.

Both reports provide summaries through extensive review of literature and highlight the factors associated with leavers/persisters and by extension migrators. A common theme in both reports highlight the Academic system to be more important than the Social system when STEM attrition is concerned. Studies [22, 23] that have investigated the social system effects on STEM attrition show no relation.

Research Questions:

1. *What leads migrators to choose AE as their first-year major?*
2. *What were their institutional experiences prior to migrating out of AE?*
3. *Considering migrator institutional experiences, why did they migrate out to other STEM majors?*

Method

Population

The first-year persistence rates for male/females in the department was 61-62% from 2010 to 2016 and slightly higher than the those reported by Costino de Cohen and Deterding (2009). The university and the department consistently appear in the top 20 Universities in terms of number of graduates and enrollment in the ASEE dataset [12]. Students who enrolled for AE between 2016-2018 at the university and chose to drop out of the program constituted as the participant pool. The specific cohorts of students were selected because the reasons for dropping out of the major would be clear in their minds and provide richer data. Information on these students were obtained from the Office of the Registrar and were sent an email regarding recruitment for the study. Emails were sent to all the students who had dropped out of the major in their first two years. In the first round of recruitment, three students responded and were not incentivized to participate in the interview. From the second round of recruitment, due to low response from the initial recruitment, students were incentivized with a \$10 Amazon gift card to which four participants were recruited. From the third round of recruitment, another two students were recruited. Out of the nine students who interviewed three were women, all white, two students were in-state (finished high school in the state), four were in an academic learning community, all stayed on campus, three were working part-time, and all had dropped out of the AE prior to their Junior year at the university. Five students had migrated to mechanical engineering, two to software engineering, one to civil engineering, and one to a business major. All data were obtained after the approval of the IRB.

Table 1 *Participant demographics*

| <i>ID #</i> | <i>Gender</i> | <i>Race</i> | <i>Instate resident</i> | <i>Learning community member</i> | <i>On Campus resident</i> | <i>Working part time</i> | <i>Semester Dropped</i> | <i>New Major</i> |
|-------------|---------------|-------------|-------------------------|----------------------------------|---------------------------|--------------------------|-------------------------|------------------|
| 1 | Male | White | Yes | Yes | Yes | No | 2 nd | Mechanical |
| 2 | Male | White | Yes | Yes | Yes | Yes | 2 nd | Mechanical |
| 3 | Male | White | No | No | Yes | No | 1 st | Mechanical |
| 4 | Female | White | No | No | Yes | Yes | 4 th | Software |
| 5 | Female | White | No | Yes | Yes | No | 1 st | Software |
| 6 | Male | White | No | No | Yes | No | 1 st | Civil |
| 7 | Female | White | No | Yes | Yes | No | 2 nd | Mechanical |
| 8 | Male | White | No | No | Yes | Yes | 1 st | Mechanical |
| 9 | Male | White | No | No | Yes | No | 1 st | Business |

Data Analysis

Pilot tests were done on three Junior undergraduate students to see if the interview protocol was apt prior to the final study interviews. These audio interviews were recorded and transcribed by the PI of the study. Each personal interview was audio recorded by the principal investigator (PI) of the study. Prior to the interviews, IRB approval was obtained, and each student signed their consent to the interviews. The final study interviews were transcribed by a professional transcription service.

To understand this complex and highly personal process of students dropping out of AE, the research tradition of Narratology was used. Narrative inquiry “revolves around an interest in life experiences as narrated by those who live them” [24] and provide a better understanding of participant realities. By connecting events that shaped their decision to leave AE over their time at the university, the participants will give personal and cultural insights which may have the potential for a larger application [25]. In addition to the personal interview, the participants were asked to give a schematic description of their experiences till they were pursuing the program. The schematic description included a timeline drawn on a white board, which summarized what the participant did before they dropped out of the AE program. The interview responses were put under theoretical categories derived from Tinto’s framework (i.e. pre-entry characteristics, social experience, academic experience, goals/commitment, and change of major. During the interview participants were asked to narrate their academic and social experiences till they were pursuing AE at the institution.

Semi-structured interview

For convenience the following definitions were explained and provided to the participants in paper at the start of the interview to refer to if needed.

“Academic: Refers to interactions with people and experiences that occur within the academic circle. This includes interactions with high school teachers, academic advisors, mentors and faculty. This also includes experiences with high school subjects, college courses, peers (friends within the department or course), and learning communities.

Social: Refers to interactions with people and experiences that occur outside of the academic circle. This includes interactions with family, friends, mentors (outside the university and school). This also includes experiences with extracurricular (e.g. fraternities, sports) activities and place of residence.”

Once the participants were familiar with the terms and its use, they were asked the following questions in order:

1. How did the social factors prior to joining the institution influence your choice of aerospace engineering as your first-year major?
2. How did the academic factors prior to joining the institution influence your choice of aerospace engineering as your first-year major?
3. On the timeline narrate your social/academic experiences prior to changing your major. At the end of every semester summarize the most important events that impacted you as a student of aerospace engineering. Explain?

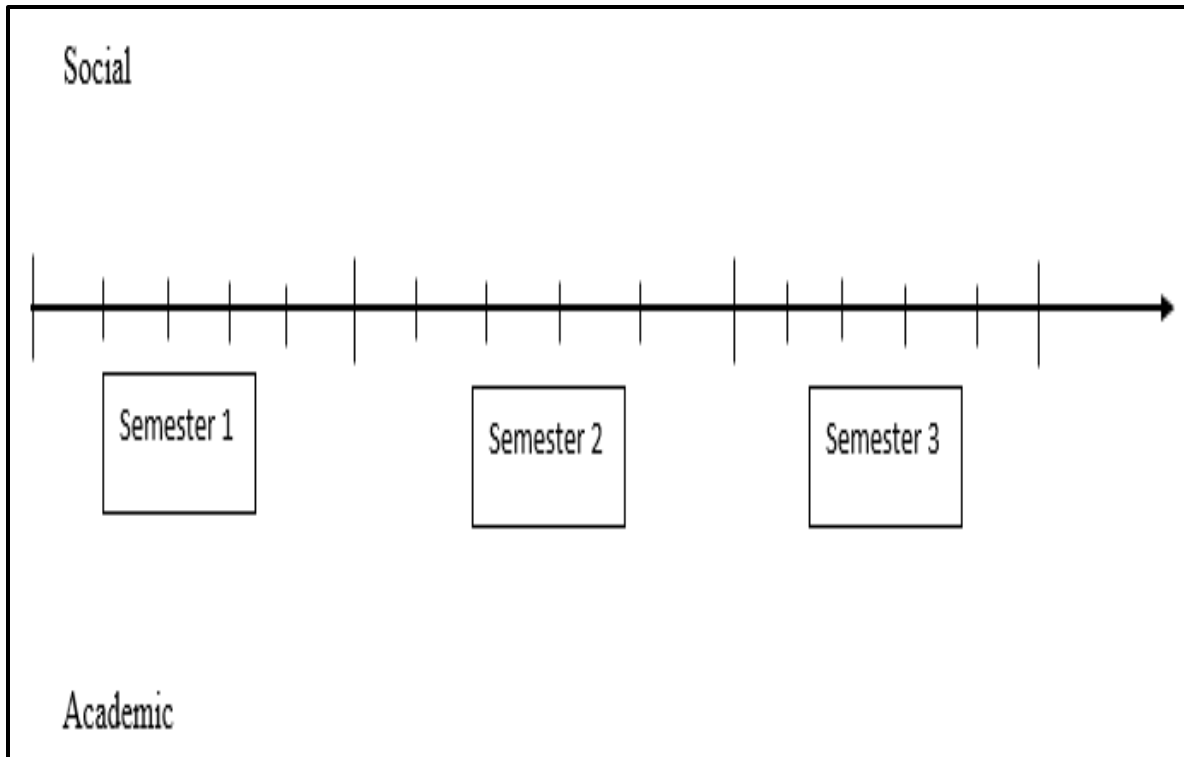


Figure 5 *Timeline drawn on whiteboard*

4. What factors influenced you to change your major?
5. Is there anything else you would like to add?

The timeline represented in figure 5 provides a general blueprint for the participants to write down their experience (figure 6, 7) while in the AE major. Participants were asked to go month wise (represented by the small dashes on the timeline) for each semester (represented by the large dashes on the timeline) they were in AE. The idea behind the timeline is that it provides a schematic description of the participants time in AE major. It acts as a tool for them to think back to their time in the major and refresh their memories so that they could provide maximum details regarding their experience. The timeline also provides a temporal ordering of the experience's participants faced to provide a better and complete picture of their time in the major and the reasons for migrating by highlighting them with an asterisk or circling them on the timeline.

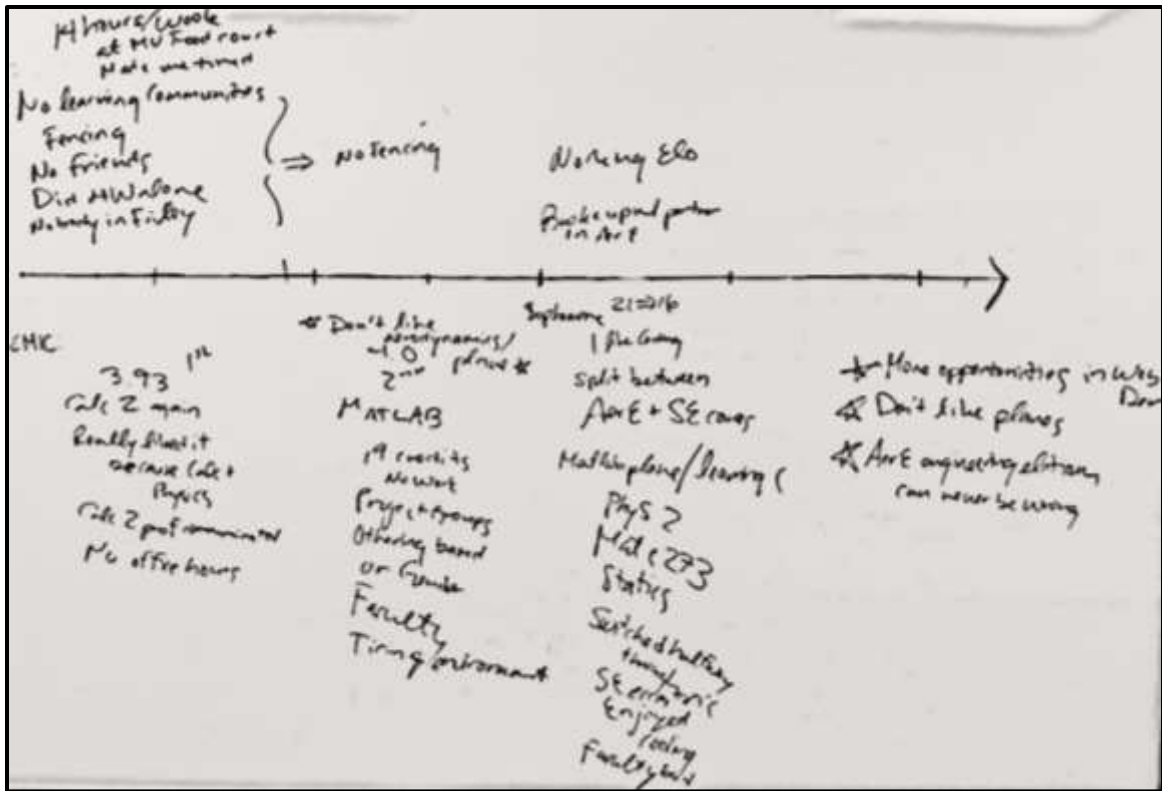


Figure 1. Example of timelines provided by students for Question 3

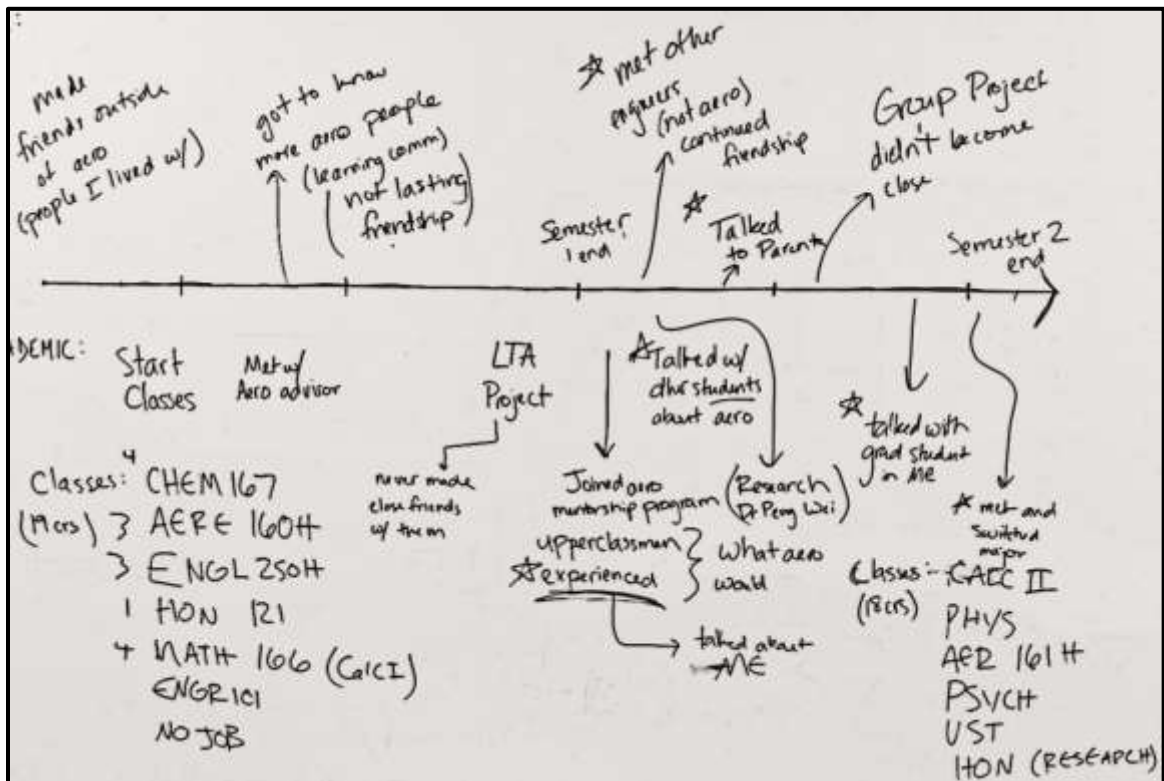


Figure 2. Example of timelines provided by students for Question 3

Inter rater reliability

Two rounds of inter coder agreements were conducted among 3 coders (the PI and two qualitative coders). For the first round an initial codebook was created by the PI along with coding instruction and distributed to the coders. One transcript was randomly selected from the 2016 cohort and coded by each coder. Coders met for discussions and group consensus on the transcripts as suggested by Saldana (2013). All differences in the coded transcripts were discussed and resolved to create a refined codebook containing definitions, description of when to use, when not to use, and examples as suggested by MacQueen et al. (1998). For the second round of coding one transcript from the remaining transcripts was selected by the PI that provided a fair representation of all the codes. This transcript was coded by all the coders and used for the next round of refinement of codes. The coding team reached consensus on all codes in the second round without refining the codebook and the subsequent transcripts were coded by the PI of the study following the instruction and definitions from the codebook. All transcripts were coded using MAXQDA.

Results

What leads migrators to choose AE as their first-year major?

From the responses of students for the first two interview questions the themes that emerged are listed in Table 2. The themes reveal that most students choose AE major because they enjoyed science/math courses in high school, thought AE was an interesting major and had high school mentors who specifically promoted AE.

Most students either did not talk about their high school friends influence or reported no influence from high school friends in choosing the major. Only one student responded saying that interactions with high school friends led to the decision to choose AE. Some students responded having special skillsets such as CAD, Simulation, and Problem-solving skills which specifically led them to choosing AE. The number of college credits in science and math varied from 4 years in advanced placement (AP) to no AP credits in science and math. Most students consulted their family when they thought about a career in engineering and were encouraged to pursue it. Although there was one student who wanted to do something other than what their family members did as a career, had no family background in engineering, and choose AE as a major. Three students reported choosing AE at the institution because the program is highly ranked in the country.

Table 1 *Count of reasons for choosing AE given by migrators*

| <i>Themes (participant ID)</i> | <i>Definition</i> | <i>Example</i> | <i>Tot.</i> |
|---|---|---|-------------|
| <i>Prior Schooling</i> | | | |
| High school friend influence (9) | High school friends influenced choosing AE | <i>“but they (high school friends) went to other universities and studied engineering, different ones, mechanical, civil. And so, I guess I found aerospace to be different, interesting, I guess.”</i> | 1 |
| AE is an interesting major (1, 2, 3, 4, 9) | AE major was of personal interest | <i>“I thought that aerospace was kind of the closest thing to like astronomy, astrophysics, like space stuff,”</i> | 5 |
| Enjoyed science/math in high school (1, 2, 3, 5, 6, 7, 9) | Chose AE major because science and math were interesting in high school | <i>“outside of science always being my favorite subjects in school. I always enjoyed physics, all that stuff.”</i> | 7 |
| High school mentor/teacher influence (3, 4, 5, 7, 9) | High school teacher/mentor influenced choosing AE major | <i>“I had a teacher that was an aerospace design engineer that he taught high school at that point. He talked about a little bit. I thought that was really cool”</i> | 5 |
| <i>Skills and abilities</i> | | | |
| CAD skills (1, 6) | Has CAD experience | <i>“in high school we had an auto-cad class”</i> | 2 |
| Simulation skills (1) | Has simulation, or coding experience | <i>“I was looking at different types of engineering, but I was starting to lean towards aerospace and then I picked CFD and stuff like that.”</i> | 1 |
| Problem solving skills (6, 7, 9) | Confident in puzzles and other problem-solving activities | <i>“I think about things more as like a puzzle I guess”</i> | 3 |
| <i>Family background</i> | | | |
| Consults family regarding engineering (1, 4, 7, 8, 9) | Talks with family when discussing engineering career | <i>“I do with my parents, just bounce ideas off of them.”</i> | 5 |
| Family encouraged engineering (1, 4, 6, 8, 9) | Family encouraged pursuing engineering | <i>“It was mostly just my family that encouraged me to join aerospace.”</i> | 5 |
| Family background in engineering (5) | Family member works in engineering | <i>“My dad's family is full of engineers and doctors.”</i> | 1 |
| Distant from family (4, 6) | Doing something apart from family | <i>“I found myself thinking a little bit differently than the rest of my family”</i> | 2 |
| Wanted to do something different (6) | No family member works in engineering | <i>“I choose it because my whole family had been in business and I had been surrounded by that my entire life, so I was pretty bored with it”</i> | 1 |
| <i>Institutional commitment</i> | | | |
| AE major high ranked (3, 6, 8) | Rank of the institution in AE is high in the country | <i>“I liked the academic program here. I guess it was ranked pretty high in the nation”</i> | 3 |

What were their institutional experiences prior to migrating out of AE?

Academic system – Formal

All *migrators* (Table 3), except participant 2, followed for the standard curriculum. Participant 1 reported performing badly in introductory Calculus and Physics while participant 3 reported that “*college is hard*” and had to spend extra studying time to maintain GPA. Four participants fondly remembered the work they did in the departmental competition. Four students got comfortable with coding languages such as Python and MATLAB during their first semester. Three students reported to have enjoyed activities which lead them to discover their new major to which they eventually migrated. Three students reported having less time to study for AE courses.

Table 2 *Count of formal academic experiences given by migrators*

| <i>Theme (participant ID)</i> | <i>Definition</i> | <i>Example</i> | <i>Tot.</i> |
|--|---|--|-------------|
| <i>Academic system- Formal</i> | | | |
| Followed advised curriculum (1, 3, 4, 5, 6, 7, 8, 9) | Followed the standard curriculum advised to first-year AE students | <i>“I was just taking calc one. I don’t know. This is always kind of the same. Calc one, chem for engineers, whatever that ... 167, is it not?”</i> | 8 |
| Did well academically first semester (2, 4, 5, 6, 7, 8, 9) | Academically did well in their first semester (self-reported) | <i>“I’ve I got a 3.86. I think I only had one A- . It was this class that was A- but the rest of the classes were A’s. If I remember correctly.”</i> | 7 |
| Enjoyed departmental competition (1, 3, 4, 9) | Enjoyed the departmental competition held for first-year AE students | <i>“Well, one thing that was really cool, I guess, about aerospace engineering, was the [AE department competition]. That was really fun. That was one of the, definitely one of the more fun things of the semester”</i> | 4 |
| Got exposure to coding (1, 4, 5, 6) | Got comfortable with coding languages such as Python and MATLAB through the AE curriculum | <i>“And then we learned some python things that was really fun actually. My group and I did work with python and that was good. We learned a lot together. And then here, this was finals week, so it wasn’t really anything new and I did pretty well on all my finals”</i> | 4 |
| Enjoyed activities not specific to AE (1, 4, 9) | Were exposed to and enjoyed activities/coursework which are not specific to AE | <i>“So, I got a B in Calc 1, but I still like, I kind of like math. I don’t love it, but I like it. I don’t hate it. So, that’s kind of why I stuck with something still a little math-based, like economics, rather than just completely gone away from it”</i> | 3 |
| Time management issues (2, 3, 4) | Reported issues with managing time to study | <i>“Right about first month of first semester, I figured out, hey, that college is hard. That it would be a lot more work. I wouldn’t be able to go through college like high school.”</i> | 3 |

Academic system – Informal

Only one student reported not liking the faculty teaching or the advising program at the department (Table 4). Except for participant 4 and participant 9, all other participants had minimal contact with faculty. All participants reported that they had minimal contact with their advisors too. Four participants reported being different from their peer. Two female participants reported facing gender discrimination at the department or learning communities. Four participants reported interacting with upper class peers. Four students reported joining a hands-on learning community or exposure to research at the department.

Table 3 *Count of informal academic experiences given by migrators*

| <i>Theme (participant ID)</i> | <i>Definition</i> | <i>Example</i> | <i>Tot.</i> |
|---|--|---|-------------|
| <i>Academic system- Informal</i> | | | |
| Disliked AE faculty/advisors (2) | Did not like the faculty teaching, thought that the faculty were not helpful, the advising program at the department | <i>“The quality of the teachers, quality and testimonials of students in upper Aerospace and interactions I’ve had with not only with the one advisor but also multiple advisors and multiple professors within Aerospace gave me a lack of confidence”</i> | 1 |
| Low interaction with faculty (1, 2, 3, 5, 6, 7, 8) | Reported that they met faculty only when required for only course related questions | <i>“I didn’t really like to communicate with faculty beyond, except in Calc two, I really liked my Calc 2 professor, so I went to his office hours a few times. And then in class, I would talk with him a lot. I feel like Calc two prof, communicated, but kind of everybody else, I just went to class and like did the homeworks”</i> | 7 |
| Low interaction with advisors (1, 2, 3, 4, 5, 6, 7, 8, 9) | Reported that they met advisors only while selecting their majors and when filing paperwork to migrate out of AE | <i>“So, my aero advisor signed it and then the adviser at [other department advisor] signed it. And then that was kind of it. I think I turned it into some office and then”</i> | 9 |
| Felt different from peers in AE (3, 4, 5, 8) | Felt that they were not as competitive as their peers and/or faced gender discrimination | <i>“I had a group that was all men, and I would kind of be more on top of stuff, and I would get stressed about how we weren’t getting stuff done. And I think people would kind of tell me, calm down a lot or call me.”</i> | 4 |
| Interacted with upper class peers (1, 3, 6, 7) | Interacted with upper class peers and/or graduate students in AE and other majors | <i>“So, I had a student, like an upper classman, who I got to talk about Aerospace”</i> | 4 |
| Joined a hands-on LC/Research (1, 5, 7, 9) | Joined a hands-on learning community or had research experience in their first semester | <i>“I joined [learning community] and [learning community]”</i> | 4 |

Social system – Formal

Only three participants reported joining extracurricular activities like sports clubs and none of the students reported participating in intramurals (Table 5).

Social system – Informal

Four students reported spending most of their time with their roommates while three students reported socializing with other residential hall students (Table 6).

Table 4 *Count of formal social experiences given by migrators*

| <i>Theme (participant ID)</i> | <i>Definition</i> | <i>Example</i> | <i>Tot.</i> |
|--|------------------------------|---|-------------|
| <i>Social system – Formal</i> | | | |
| Joined extracurricular clubs (2, 6, 9) | Joined extracurricular clubs | <i>“I’m also a part of, it’s called Lacrosse”</i> | 3 |

Table 5 *Count of informal social experiences given by migrators*

| <i>Theme (participant ID)</i> | <i>Definition</i> | <i>Example</i> | <i>Tot.</i> |
|--|--|---|-------------|
| <i>Social system – Informal</i> | | | |
| Close relationship with roommate or small group (1, 2, 4, 8) | Reported spending time and/or did homework with roommates or in small groups of 2 or 3 friends | <i>“Most the time I spent was hanging out with my roommates or studying Calc 3.”</i> | 4 |
| Socialized in residential hall (3, 6, 8) | Reported interactions with other residential hall students | <i>“And then I was living in [residential hall name], so I would hang out with, I was with these random roommates, I would hang out with the random roommates sometimes.”</i> | 3 |

Considering their institutional experiences, why did students of AE migrate out to other STEM majors?

Participant 1

The participant thought about migrating for about two months prior to switching midway through his second semester to ME. The participant did not work part time.

Reason for migrating:

“Pretty much that half of the semester up to it. I think it was around, might have been over break that I kind of started thinking about it”

Participant 1 reported that his general interest declined in AE declined after joining a hands-on learning community where he did not get the opportunity to work with AE related activities (such as computational fluid dynamics).

“I was actually trying to do aero-related stuff, but most of the aero stuff for the car had been done”

The participant enjoyed the non-AE related activities he did instead.

“But a lot of what I was doing wasn't aerospace-related, which is ... And I was enjoying it, so I was kind of like, Is this what's right for me?”

The participant also reported that getting a job in AE is tough because of the competition which he found out from upperclassmen and his personal experience at the career fair.

“I was talking with other [hands-on learning community] members about what future aero and ME was like. And then I guess on top of that another thing that came up in talking with them, jobs is something that always comes up, and aerospace is kind of ... When you go to the career fair, the companies are always extremely busy and then they never want to talk to you when you're a freshman or a sophomore, pretty much.”

The participant also received a low grade in introductory math class which made him think that it would be a barrier for him if he continued in the major.

“I was doing bad in math was I did hear that math is a bit more involved higher up in aero then I was kind of like, Well, if I'm not doing good at math then I might not do good further on.”

Participant 2

The participant switched out of AE “within the first semester” to ME. The participant worked part time as a tutor and reported to have time management issues due to work.

Reasons for migrating:

Participant 2 reported negative experiences regarding advising and faculty.

“I was probably at the point where I was I didn't like how it was structured (advising) or I also did not like the teaching style of the professors that I had encountered in Aerospace”

Participant 2 also reported that his general interest in AE declined because it was too specific and would have a broader range of career options with ME.

“I looked at different majors with an engineering because I know that's the path I wanted to go down. Mechanical engineering was... its very very broad. It gives me a lot of options and versatility to go so that's why I decided to go mechanical.”

Participant 3

Participant 3 thought about migrating “midterm of first semester freshman year” and switched to ME right before the end of first semester. The participant did not work part time.

Reasons for migrating:

Participant 3 reported that his general interest in AE declined because of AE related courses.

“It was like thermodynamics and the fluid flow and everything like that. It was so-so for me. I was like, well, mechanical might have a lot more stuff that I'm interested in,”

Participant 3 reported that getting a job in AE is tough because of the competition which he found out from the institutions career fair statistics.

“Aerospace is so competitive. Like 800 people graduating, like 60 some jobs opening up every year. I did some research and with that.”

Participant 4

Participant 4 thought about migrating in her third semester and switched to software engineering (SE) halfway through third semester. The participant worked part time as a food server during her first semester and in IT support for the university during her sophomore year.

Reasons for migrating:

The participant reported that she enjoyed non-AE related activities.

“I liked coding”

Participant 4 reported that getting a job in AE is tough because of the competition which she found out from her personal experience at the career fair.

“I remember that (institution career fair experience) continuing to be something that really discouraged me in aerospace. And I think it was like, one of the reasons that I left aerospace was that I didn't feel very hireable among, there's a lot of engineering elitism in aerospace.”

Participant 5

The participant switched to SE during first semester finals. The participant did not work part time.

Reasons for migrating:

Participant 5 reported her general interest in AE declined after her personal experiences with industry professionals (in AE and other engineering) at a conference organized by a learning community with a female majority.

“And so in between there and then it was just basically after I joined the two clubs and they both just kind of showed me that I was not ... I was kind of faking the excitement of how excited I was about engineering. For everyone else it seems so natural”

Participant 6

The participant thought about migrating “December going into dead week” first semester and switched to CE during the first week of second semester. The participant did not work part time.

Reasons for migrating:

Participant 6 reported that his general interest in AE reduced because it constrained his future career options.

“I'd already talked to people from other departments and I'd talked to other classmates in those departments. Or that were in that field so that, I would say that really influenced me just everyone else that I talked to just simply answering my questions.”

Participant 7

The participant thought about migrating starting of second semester and switched to ME end of second semester. The participant did not work part time.

Reasons for migrating:

Participant 7 reported that her general interest in AE because it constrained her future career options.

“I think I'd like to say the reason I switched isn't because I necessarily didn't like Aerospace is cause I'm not sure that is what I want to do for the rest of my life. I don't know what I want to do so that is why I switched, cause I have more options in Mechanical.”

Participant 8

The participant thought about migrating middle of first semester and switched to ME officially end of first semester. The participant worked as an office assistant and reported that he was able to balance his work and school time well.

Reason for migrating:

Participant 8 reported that his general interest in AE reduced because he did not like AE courses.

“I think this (introductory AE course) was the one that kind of drove me away the most.”

Participant 9

The participant thought about migrating “about two months until the end of the school year” and switched to Business at the end of first semester. The participant did not work part time.

Reason for migrating:

Participant 9 reported that he enjoyed economics more than AE related courses.

“The reason I switched, I did switch, not because I didn't like aerospace, but I liked economics more.”

Summary

Table 7 provides a summary of all the reasons given by the migrators for leaving AE.

Table 6 *Count of reasons for leaving AE given by migrators*

| Code | Definition | Example | Tot. |
|---|--|---|-------------|
| Constrained career options (2, 5, 6, 7) | AE major limited their future career options | <i>“It felt really specific and I don't really know exactly what I want to do as far as with an engineering degree.”</i> | 4 |
| Did not like AE course (3, 8) | Did not like the introductory AE course | <i>“I think this (introductory AE course) was the one that kind of drove me away the most.”</i> | 2 |
| AE job market is competitive (1, 3, 4) | To get a job in AE is tough and competitive | <i>“I need to be here for a purpose and if I don't get a job at the end then college is kind of like worthless. It was a high-risk major.”</i> | 3 |
| Enjoyed non-AE activities (1, 4, 9) | Enjoyed academic activities not specific to AE | <i>“I get to do all this design work, I get to do all this hands-on stuff, it was really fun. But a lot of what I was doing wasn't aerospace-related,</i> | 3 |

| | | | |
|--|--|--|---|
| Bad performance in introductory college math (1) | Bad grade in Calculus | <p><i>which is ... And I was enjoying it, so I was kind of like, "Is this what's right for me?"</i></p> <p><i>"I was doing bad in math was I did hear that math is a bit more involved higher up in aero then I was kind of like, "Well, if I'm not doing good at math then I might not do good further on."</i></p> | 1 |
| Negative informal academic experience (2) | Did not like the faculty teaching style and advising | <p><i>"I was probably at the point where I was, I didn't like how it was structured or I also did not like the teaching style of the professors that I had encountered in Aerospace"</i></p> | 1 |

Discussion

All students selected AE as their major because they had a high school mentor who influenced them, or they enjoyed science and math in high school. They had varying preparation in high school math and science ranging from none (e.g. participant 1) to 4 years (e.g. participant 7). Participant 2 even ended up taking advanced curriculum which included advanced calculus (i.e. Calc 3) in his first semester. A key finding here is that while students discussed and consulted with family regarding engineering only one student (i.e. participant 5) reported family background in engineering and hence selected a major in engineering. As highlighted by previous literature [2] students with weaker academic backgrounds tend to drop out of STEM majors. Each of these *migrators* had strong academic backgrounds shown by their special interest/experiences in high school/math or science. While these *migrators* reported analytical skills and prior schooling in math/science, variables essential to persistence and academic success in AE [29], it was not enough to keep these students committed to a career in AE. Even students who showed special interest in AE prior to joining the institute and students who joined the major because the department ranking is high migrated to other STEM majors. This clearly implies that only Pre-entry attributes of a student are not enough to motivate students to pursue a career in AE and institutional experiences play a key role in this decision.

Almost all *migrators* followed the standard curriculum and did reasonably well in their first semester implying that the course load set by the department was not a hindrance to them in staying motivated to pursue the major. Four participants remembered the departmental competition fondly, but it was not enough to keep them motivated towards a degree in AE. Four students reported being exposed to coding languages implying that some first-year students do not come into college with basic coding skills which need to be taught in the introductory courses. Three students were exposed to experiences and skills (e.g. coding, economics) during their time in AE which were not necessarily AE related and eventually moved to that major. Almost all *migrators* reported low faculty and advisor interaction. Four *migrators* reported thinking that their peers were very competitive and felt different from their peers in the introductory AE course and learning communities. Four *migrators* reported interacting with upper class students at fraternities, learning communities, and at the department. Four participants had joined hands on learning communities or even had research experience at the department. *Migrators* usually did not participate in more than one extracurricular activity. Four *migrators* reported close relationship with their roommates which included doing homework

together and spending leisure time while other reported socializing with other residential hall students. Qualitatively speaking, these migrators reported more interactions and experiences in the academic system than in the social system which consistent with previous literature [29].

One student reported migrating because of bad performance in the introductory courses (i.e. participant 1) and another student reported negative teaching and advising experience (i.e. participant 2). It is important to note that participant 1 reported no AP credits in high school and would have found the new concepts of Calculus and Physics tough at least as compared to his peers. Performance in Calculus and Physics clearly impacted his identity as an AE engineer. These two student reasons for migrating are like the student reasons for leaving STEM [14, 15]. Two out of three students (i.e. participant 2 & 4) who worked reported issues with time management which is in line with *persisters/leavers* literature. Tyson (2012) showed that some *leavers* faced issues with time management due to working part time which could cause student-faculty relations to be constrained as students were not able to devote their time to studies. Participant 2 displayed such characteristics by constantly highlighting time management issues due to work and extracurricular activities, and negative informal academic experience. Three students picked up the skills required in their future majors (to which they migrated to) and the motivation to pursue it during their time in AE. Surprisingly each of these students had reported that AE was a major of personal interest to them prior to joining the university and have now migrated out of AE because their career choice has changed. This implies that the department provided great exposure to aspects of other majors to these students through the curriculum designed for AE. Choosing a major in engineering does not translate to career commitment [18, 30].

Three students reported that AE is a competitive major because the ratio of jobs to graduates is very high and it would be difficult to obtain a job. Reports on AE workforce [3, 4, 5] point towards increase requirement of graduates and expansion of the workforce. Investigating further on why these students have the opposite notion of the industry and its workforce reveals:

“I remember being really surprised and upset; how big the aerospace lines were.... And I go to career fairs and the lines were really long and I can't really talk to anybody..... I would say like the main reasons, like I'm not in aerospace any more, is that I wanted a job that would allow me more kind of space, cause in aerospace it kind of felt like you were trapped between three companies (AE companies at institution's career fair)”–Participant 4

The first real exposure these students had with the industry was through the career fairs held at the institution or from upper-class peers from the institution. This impression of lack of jobs and the competitive nature of the industry came from their contact with professionals in the career fair which may not be correct. The institution's career fair incorrectly represents the number of AE companies in the country leading these students to believe that the jobs in the industry are few. The larger issue is that these first-year/sophomore students are being advised by their upper-class peers who also believe the same. None of the students reported to have spoken to advisors or even faculty regarding such concerns about the industry.

Four students reported that their interest in AE had dwindled because it constrained their future career options and hence migrated out of the major. Two (i.e. participant 3 and participant 8) students reported not liking AE courses and, hence migrated. Interestingly four of the five

students who migrated to ME fell under either of the two groups. All six of these participants did not provide a specific motive like those that enjoyed non-AE related activities (i.e. participant 1, participant 4, participant 9). Student who transferred to ME mostly expressed this concern and migrated to have broader career options.

“It felt really specific and I don't really know exactly what I want to do as far as with an engineering degree.” – Participant 8

Previous literature on *migrators* report that *leavers* experience the same issues as *migrators* with the only difference in choice of the next major i.e. STEM or non-STEM. In addition to these issues, AE *migrators* face the added challenge of misinformation regarding the industry. AE *migrators* are under the impression that they may not get a job in the industry even if they get a degree in AE because there are simply not enough jobs. The converse of which is true where the industry workforce is undergoing increased expansion which the graduation rates have not kept up with (at least as compared to other engineering disciplines). Bearing in mind that the institution is among the top 20 schools in terms of AE enrollment and graduation [12], the institution is not getting the adequate attention it requires from the industry (at least as compared to other engineering disciplines like ME or SE) to promote the reality of AE jobs in the industry.

Implications

To increase retention in AE it would make sense to retain first-year students in the major who have the required skills (i.e. *migrators*). All *migrators* reported low faculty, and advisor interaction and could have benefited from how to communicate with professors and advisors. The department may want to provide supplementary instruction/tutoring for Physics, Calculus, and basic coding for students who require it (e.g. students who lack AP credits in math/science). First-year students selecting AE major may not have obtained the required schooling/skills required to succeed in the major which may be overwhelming. Migrators although no longer motivated to pursue AE still enjoyed the departmental competition which may provide opportunities for students to socialize with their peers. In the study six of the nine migrators had the skills to pursue AE and are pursuing engineering currently migrated simply because they thought it constrained their future career options or did not like some aspects of the introductory AE course. The results imply that students who migrate out of AE do so because they think AE is a competitive field where jobs to graduates ratio is low, and to have broader career options. These students started thinking about their professional careers and may have jumped to such conclusions about the AE industry early. To counter the effects of misinformation regarding AE, the department should generate basic reports made for aspiring AE students and their parents regarding the AE industry where trends about job placement and enrollment in the country are explained. Such reports may be made accessible on departmental website (e.g. 31, 32) departmental job boards, emails, and even during orientation of students in AE. Students pursuing AE should be encouraged and taught to expand their job/internship search through online portals and networking to counter the low representation of the industry in the university's career fair.

Limitations and Future Studies

The inferences made in the study are limited in its applicability to other institutions, and that the sample participant pool was only made up of the majority population (i.e. White). The minority population in AE may face more challenges in the addition to the ones mentioned in the study. Future studies should focus on the impact of career fairs on first-year AE students and its effects on their goals and commitments towards pursuing a degree in AE. Future studies should also explore the impact of socialization in the departmental competition and how it can help keep students motivated towards pursuing a career in AE.

The impact of race/ethnicity and gender in AE were outside the scope of this study due to low sample size which future studies must explore qualitatively. Such disparity exists in AE and it begins at the undergraduate level. To be more specific, universities may want to look at impact of teams in early years, motivation strategies specifically through various AE organizations, and advising. The women in this study followed advising, did academically well in their first semester, and enjoyed STEM activities promoted by the department. While this may be ideal first year student behavior, they also mentioned low interaction with faculty and advisors. Two out of the three female participants reported gender discrimination from their peers which may have led to loss of motivation. These women followed the initial advice and did well but seemed to have lost motivation to pursue AE along the way.

Conclusions

AE workforce is facing a dire requirement of graduates in the workforce over and above the requirement by any other engineering field due to the special requirements of nationality and security clearance to obtain a job. Promoting persistence among students aspiring to get a degree in AE and subsequently working in the field is one of the ways to fill the requirement of graduates in the industry. Studying persistence trends among students starting in AE major reveal that they fall behind the cumulative engineering trends implying that these aspiring AE students are facing added challenges. Most participants reported migrating as their interest dwindled in AE because of the major being competitive to get a job. This sentiment, although untrue, has been attached to AE for some time and has caused these students to migrate out of AE. While the AE industry usually hires graduates from other majors, it is unlikely that these *migrators* would pursue a job in AE because of this initial experience. The results of the study raise serious concerns about this negative contact and misinformation regarding AE and were only highlighted by studying the diverse individual experiences of these *migrators*.

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