Disciplinary Migration of Engineering Master's Students: Why do Some Students Change their Majors and Others do Not?

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Introduction

While there is a body of research that explores the reasons students change majors during their undergraduate degree, similar work has not been done to understand changes in discipline that students may make between an undergraduate and graduate degree. We investigated these students, who we call disciplinary migrators, using both quantitative and qualitative analysis methods; a survey was conducted, and some survey participants were selected for later interviews. The study in this paper focuses specifically on disciplinary migration that occurs from the bachelor's to the master's for students whose undergraduate degree is in a Science, Technology, Engineering, or Mathematics (STEM) field and whose graduate degree is in some field of engineering, and sets out some characteristics of these students.

Literature Review

Studies have been performed to understand why students switch majors at the undergraduate level, especially in Science, Technology, Engineering and Mathematics (STEM) fields [1]. However, no similar studies have been performed to determine why students switch majors at the graduate level from what they previously studied in their undergraduate degree. Since findings of an earlier study suggest that graduate student decisions are affected by some of the same factors that influence an undergraduate student [2], this literature is relevant to the current study.

There are many factors that contribute to a student's desire to switch or migrate into a different major. In the STEM fields in particular, a common reason is that STEM departments are the most difficult grading departments at most colleges [1]. Other students become less interested in the course work of their declared major or discover a preference for courses taken in other programs [3], while others perform poorly or find themselves otherwise unsuited for their current program of study [4]. Furthermore, students may discover better career and employment opportunities from majors that prepare them for a different field [4, 5]. In the ideal case, switching to a different major provides students with a means to increase their satisfaction with studies [6] and is not rooted in attributes of character or ability [7]. Lucietto [8] later advanced Seymour and Hewitt's earlier finds, directly refuting one of the assumptions that academic ability is a predictor of persistence in a choice of major. It should be noted, however, that Seymour and Hewitt [7, 9] and Strenta et al. [10] only studied high achieving undergraduates. While high achieving undergraduate students are different from typical undergraduate students, one may speculate that they are the students who are more likely to pursue graduate studies. A handful of studies [11, 12, 13] found this to be true; they found that students of greater academic achievement at their undergraduate level are most likely to pursue graduate study. Though there are many facets of academic achievement, one of the key determinants is a student's GPA. It is reasonable, then, to hypothesize that students with a higher GPAs are the ones more likely to pursue graduate study. A later study gave credence to this; it reported that individuals with higher GPAs are most likely to enroll in advanced degree programs [14].

Moreover, additional research has focused on factors relating to why individuals persist in a particular major [15, 16, 17], using components from Holland's theory of careers [18]. Part of the

general findings revealed that students who have earned a high first-year GPA are more likely to persist in the initial major than those who earned lower grades [15, 16]. Rask and Tiefenthaler [19] corroborate this finding; they found that lower grades led to lower persistence, and that the reverse is also true. Additional reasons why people persist include the type of institutions that the students attended and their educational experiences at these institutions [2].

Understanding individuals' motivation for graduate study is also important in studying disciplinary migration. Some people may choose to pursue graduate study for their own personal academic development, but there are those who desire to change careers and an advanced degree helps them to do so [20]. This line of argument was earlier furthered by Malaney, who cites as common reasons for graduate study the desire to learn more about a specialty, personal satisfaction, improved job prospects, and an advanced degree needed for advancement within a chosen field [21]. Similar findings are described in a study by Gagnon and Cocolas [22]. Other students may not want a complete career change, but may wish to change their focus somewhat, and feel that a graduate degree would facilitate this [23]. This desire to change careers or career focus could call for one to study a major that is different from their undergraduate major thus contributing to the argument above about why people switch majors at the master's level, and therefore is very relevant to disciplinary migration.

Methodology

This investigation was carried out through a mixed method study, utilizing a survey administered over the web using Qualtrics and a follow-up interview. The dataset originated from an earlier study that explored differences between Direct-Pathway and Returner graduate students [24, 25]. This survey contained sections on demographics, academic information and experience, confidence, alignment of the master's degree with work, academic advising, and choice of school, future plans, and motivation for graduate study.

Participants

Participants for the survey were recruited by rolling recruitment over a period of four months. In accordance with the IRB-approved protocol, all survey data was anonymized and confidential. A total of 299 people completed the survey, 40 of whom were subsequently interviewed. All participants were engineering master's students; some were terminal master's students while some were enrolled in a joint PhD program or were planning to continue to a PhD. They were drawn from a wide range of universities in the United States, with an aim of obtaining diversity in pathways, experiences, perspectives and geographies. All participants were United States citizens or permanent residents, due to the large number of variables that would be introduced from an international student population [25, 26]. Participants' demographic information from the survey and interview data are displayed in Tables 1 and 2. It is noted that in some cases, participants chose not to report their gender. Note also that participants could, and did, specify more than one racial or ethnic identity.

Table 1: Demographic Information from Survey Data

Disciplinary Migrators	200
Non-Migrators	95
Females	66
Males	142
Median Age	25
Ethnicity	
American Indian	5
Asian	49
African American	11
Hispanic/ Latino/a	18
White	226
Other	5
Unanswered	6

Table 2: Demographic Information from Interview Data

Disciplinary Migrators	17
Non-Migrators	24
Females	12
Males	29
Median Age	>25
Ethnicity	
American Indian	0
Asian	3
African American	3
Hispanic/ Latino/a	1
White	35
Other	0
Unanswered	0

Data Analysis

The quantitative data from the survey was analyzed using standard descriptive and inferential statistically methods. These analyses were carried out using the Minitab software package [27]. A variety of hypotheses were examined, using p values to determine which were valid.

In the interview phase of the study, participants described their decision-making process as they chose to pursue a master's degree with follow up questions about the challenges they experienced in the program, as well as whether and how their past experiences interacted with or influenced their education. The interviews were audio recorded and transcribed, with any identifying information removed.

The qualitative data from these interviews were analyzed using open coding to construct new theories as they emerged from the findings [28]. Each transcript was studied individually to identify themes that correlated to the students change patterns. Subsequent to the coding, disciplinary migrators and students who carried on with the same discipline at the graduate level were grouped separately to compare and contrast differences in perspectives.

Findings

Survey Findings

In analyzing the survey, we have six key findings. In analyzing for statistical significance, the standard test was used, i.e., 95% confidence level.

1. *A greater proportion of survey participants changed discipline than stayed in their original, undergraduate discipline*

   Out of the survey population of 299 participants, 202 were disciplinary migrators, with the remaining 97 continuing their graduate degree in their original discipline, as shown in Figure 1. Therefore, it can be stated that in this study, students are more likely to migrate to a new discipline than to remain in their original discipline.

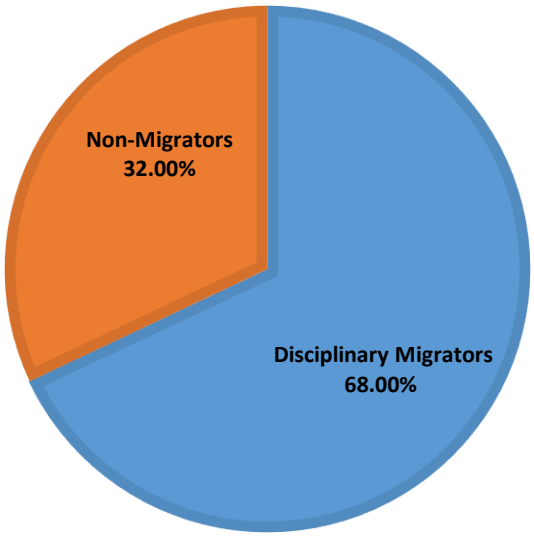

Figure 1: Proportions of Disciplinary Migrators and Non-Migrators

2. *Disciplinary migration is not random; some pathways are more common than others.*

The migration patterns of survey participants are shown in Figure 2. Those participants who fell on the diagonal are those who continued with the same discipline, while off-diagonal cells represent disciplinary migration. Subject areas that received a high percentage of students from some other specific discipline are highlighted in red. This shows that a significant number of people are changing into certain fields, e.g., Industrial Engineering and Computer Science. It is also evident that people with Mechanical Engineering bachelors tend to have the widest spread of people going into different majors at the Master's level. Biomedical and Electrical Engineering have the highest retention rate, with few of their undergraduates migrating to another discipline for their master's degree. Further, it can also be seen that participants in this study had a 100% migration out of Applied Physics into other majors at the Masters level however, there were only 2 survey respondents in Applied Physics at the Bachelors level to begin with. The breakdown of survey respondents who started in each major is given in Table 3.

Table 3: Undergraduate Discipline of Survey Respondents

Undergraduate Major	**# Survey Respondents**
Aerospace Eng.	21
Applied Physics	2
Biomedical Eng.	15
Chemical Eng.	25
Civil Eng.	34
Computer Sci/Eng.	28
Electrical Eng.	33
Industrial Eng.	11
Mechanical Eng.	61
Other B.Sc.	69
Total	299

	Aerospace M.Sc.	Applied Physics M.Sc.	Biomedical M.Sc.	Chemical M.Sc.	Civil M.Sc.	Computer Sci /Eng M.Sc.	Electrical M.Sc.	Industrial M.Sc.	Mechanical M.Sc.	Other STEM M.Sc.	TOTAL
Aerospace Eng B.Sc.	38%					5%		5%	10%	43%	100%
Applied Physics B.Sc.		0%						50%		50%	100%
Biomedical Eng B.Sc.			73%					7%	7%	13%	100%
Chemical Eng B.Sc.			8%	52%					8%	32%	100%
Civil Eng B.Sc.					65%	3%			3%	30%	100%
Computer Sci/Eng. B.Sc.						61%	7%			32%	100%
Electrical Eng B.Sc.						6%	76%			18%	100%
Industrial Eng B.Sc.						27%		36%		36%	100%
Mechanical Eng B.Sc.	5%		7%		2%	3%	2%	8%	41%	33%	100%
Other STEM B.Sc.	4%		4%	4%	7%	10%	1%	6%	9%	54%	100%

Figure 2: Disciplinary Migration Patterns

3. *Older students are more likely to be disciplinary migrators.*

   There are similar patterns in the age distribution of disciplinary migrators and non-migrators, as shown in Figure 3. However, statistical tests do indicate an age difference for the two groups. The proportion of people who change their discipline is higher among those participants who are at or above the age of 35; a lower percentage of disciplinary migrators is present in the group of participants who are under 35. It is important to note that a similar pattern can be seen if such an analysis is carried out based on "gap years", the number of years between participants completing a bachelor's degree and beginning a master's degree. Significant work has been done on returners in graduate programs [23 – 26, 29 – 31]; it is not known, in this case, which correlation is most relevant.

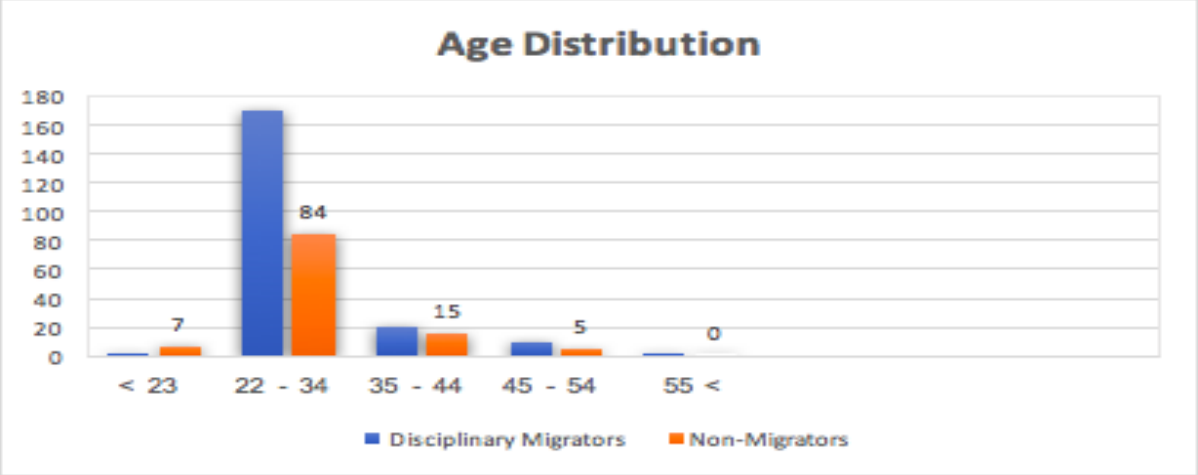

Figure 3: Age and Disciplinary Migration

4. *While disciplinary migrators have a higher average GPA in their master's program than non-migrators, during their undergraduate program the disciplinary migrators had a lower average GPA than non-migrators.*

   Analysis of GPA data among the survey respondents shows that there is a correlation between a lower average undergraduate GPA and migration into a new discipline. However, there is also a correlation in the opposite sense at the master's level; those who migrated to a new discipline have a higher average GPA in their master's program than those who did not migrate to a new discipline. The GPA distribution for both populations is given in Figure 4, with the average GPA and its changes shown in Table 4.

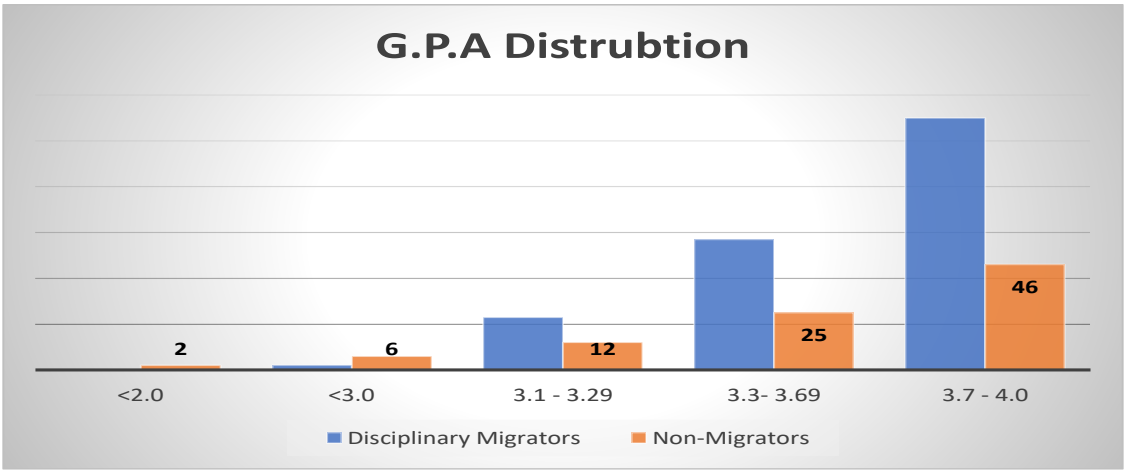

Figure 4: GPA Distribution for Disciplinary Migrators and Non-Migrators

Table 4: Changes in Average GPA for Disciplinary Migrators and Non-Migrators

Participants	B.Sc. GPA	M.Sc. GPA	% Change
Disciplinary Migrators	3.27	3.5	7.04
Non-Migrators	3.36	3.39	0.9

5. *Disciplinary migrators and non-migrators have equal levels of confidence as they prepare to take the GRE, and performed equally well on the GRE.*

   In the survey, students were asked about their overall confidence before taking the GRE, as well as about their performance on the test. As shown in Figure 5, it was found that disciplinary migrators and non-migrators had similar levels of confidence about the test. After taking the test, they had similar levels of performance; disciplinary migrators had an average GRE verbal score of 156.6 and a quantitative reasoning score of 156.4; non-migrators had average verbal and quantitative scores of 155.4 and 158.4, respectively, which did not represent a statistically significant difference.

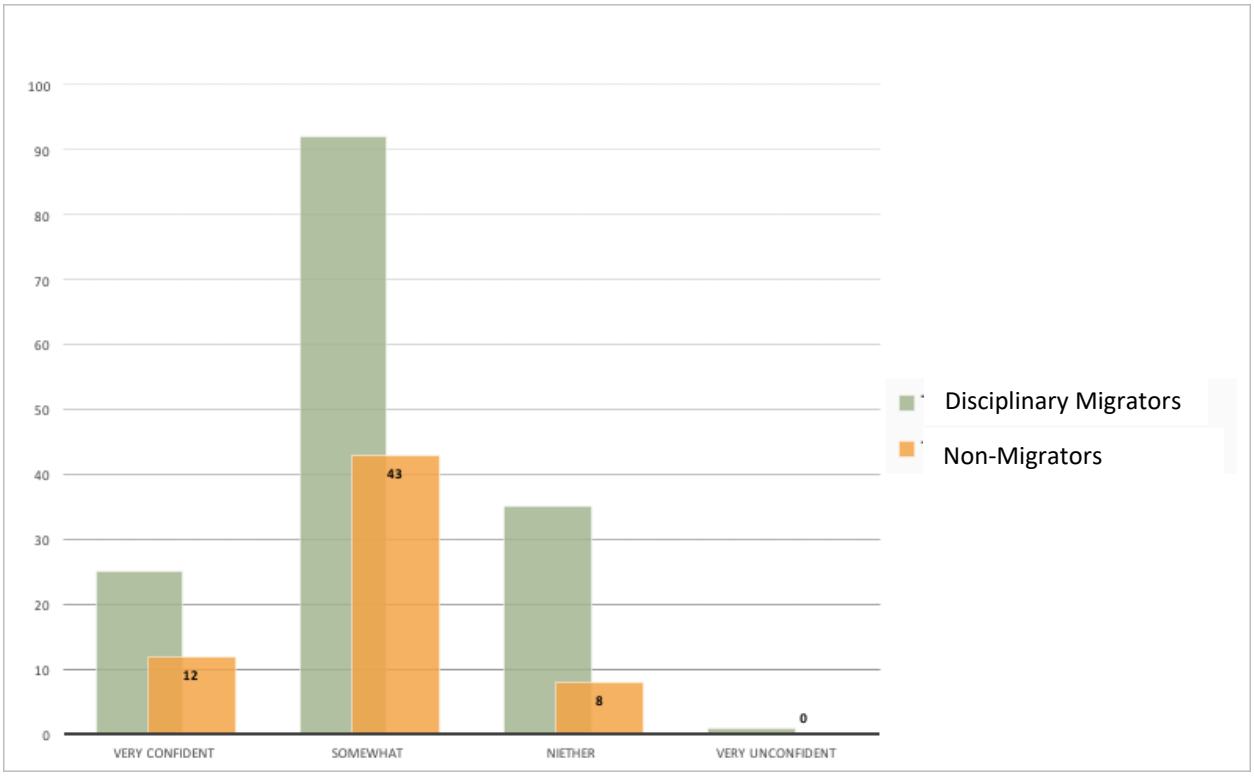

Figure 5: Confidence Level for Disciplinary Migrators and Non-Migrators

6. *There is a relationship between disciplinary migration and the alignment of a master's program to a participant's job.*

   In the survey, participants were asked about the degree to which their graduate program was aligned with their job, if they were employed; this question employed a Likert scale, going from a low of 1 (not at all aligned) to 5 (very well aligned). While not all participants were employed, many were; and the results showed that disciplinary migrators reported a significantly higher degree of alignment between their job and their degree program than did non-migrators.

Interview Findings

Interview data revealed that the participants in our study all had definite reasons why they were migrating into other programs, but the reasons differed from one participant to the next. The explanations as to why they selected the programs they chose to pursue at the master's level can be put into four main categories: career exposure, specialization, marketability, and availability. These categories are explained in more detail below, with sample quotes from some of the participants given to further illustrate them. Note that, in some cases, a participant could have more than one reason for his or her program, and could fall into more than one category.

Career Exposure

Two participants, Luyanda and Romaine, wanted to pursue a different major from their undergraduate education after getting exposure to industry. In choosing their graduate program, they were motivated to do something better aligned with the tasks they were performing at their jobs. Luyanda, who pursued Electrical Engineering at the undergraduate level, migrated into a Computer Science masters because of the exposure he was getting working at a software company.

> I knew that I wanted to do, I thought I wanted to do CS coming out of undergrad, working with <redacted>, in working through miserable days, but on concepts I liked solidified that I wanted to do this. They say you have to love the failure in order to be a great player, basketball player, sports player, or whatever

Romaine had a similar story, with his career exposure directly impacting what he studied at the masters' level. His undergraduate degree was in Meteorology but he ended up pursuing a masters' in Civil and Transportation engineering.

> The reason I went back to get into engineering ... civil engineering and transportation specifically, was what I was exposed to at <redacted>. I saw a lot of things I wanted to improve and I didn't have the tools, I thought- the analytical tools, some of the background…

In his case, the masters' degree would provide what he needed to accomplish his goals of problem solving in his current role. These two cases demonstrate how career exposure can impact not only an individual's drive to pursue graduate study but also their program of choice.

Specialization

One participant, Jessie, started working in the aerospace industry after completing his bachelor's degree in mechanical engineering. His experience in aerospace not only encouraged him to migrate into the aerospace discipline for his master's degree, it also pushed him to seek one of the discipline's highest qualifications, becoming a Designated Engineering Representative (DER).

> I wanted to become structure DER, a designated engineering representative for structures stuff, so at that point I will become a knowledge expert for that.

A DER is an individual, appointed in accordance with FAA Part 14 CFR 183.29, who holds an engineering degree or equivalent, possesses technical knowledge and experience, and meets the qualification requirements of FAA Order 8100.8D [32]. In other words, DERs are the only engineers who may approve, or recommend approval, of technical data to the FAA for their company.

Though Jessie's career exposure to the Aerospace industry was a factor that caused him to pursue an aerospace master's his desire to specialize or in his words – 'become a knowledge expert' was very pivotal to his choice of master's degree.

Marketability

In some cases, people migrate into certain disciplines at the masters' level in order to be more in 'demand' for the job that they aspire to have. Jessie, Chad and Sydney are examples of individuals who did this. In addition to his desire to become a DER, as explained previously, Jessie also wanted to stand out and be more marketable in his field. He was aware that bad economic conditions can affect jobs, and wanted to be able to withstand those difficulties.

> … I want to go this route and I want to make myself more marketable, I am secure at where I am working and probably going to be there for a long time, it's just what happens when something goes wrong, then what do you do?...

Chad, on the other hand, had a background in both mechanical and material science engineering, but decided to go straight into graduate school after undergraduate for material science engineering only.

> People look at my resume and they say like, "Oh, he wants to do material science and mechanical, because he's both." But absolutely with the master's I can really say, "No, I'm way more interested in the material science.

Chad was only getting 'mechanical engineering' type jobs – not what he wanted. His migration, therefore, was to become more marketable in one of those two areas, by moving away from the other.

> The choice of going into material science school almost was like a comforting one, because it was, one, scary going into the work world, the actual career, but also because none of my job offers were really ideal or maybe what I wanted to go into.
>
> I didn't want to work at a steel manufacturing plant, like in the Midwest or something.

Sydney, unlike Zach and Chad, did not start off in engineering. Her undergraduate degree was in physics. She soon realized that she did not want to continue with the discipline into the master's level.

> Physics was my undergrad and then I switched because I realized the only way you're going to make it anywhere in physics is if you get a PhD and you're the top like two percent in the field. That's the reality of it.

What Sydney shares in common with Jessie and Chad, though, is the fact that she migrated into a new discipline (in her case, nuclear engineering) at the master's level because she thought it would provide her better job opportunities than her undergraduate discipline had given her.

> I was like maybe I should get a practical and marketable field like engineering, and then I tossed up things like aeronautical engineering, because I didn't ride a plane until I was maybe 20, 19 or 20 and I loved it… I applied at <redacted> for the nuclear engineering, and was like, "Well you know, who knows? Maybe I'll get in, maybe I won't." And then I got in and then I came here.

These three participants choose to migrate into new STEM disciplines at the master's level because they believed that those specific programs of choice would yield them better opportunities and make them more hirable/marketable for the jobs they wanted.

Availability

Some participants choose to migrate into different engineering disciplines at the graduate level not because they have some deeper affinity for these programs but simply because they might have enrollment options (for example part time and online options) that work better with their schedules.

Three of the participants in this study, Micah, Rashida, and Rohan, are examples of this type of disciplinary migrators. Micah, who studied math at the undergraduate level, went on to become a manager at a Fortune 100 company and did not want to have to give that up in pursuit of his graduate ambitions. Therefore, he found an online Operations Research master's program that would meet his availability constraints.

> Yeah, so there were a couple constraints. There were some geographic and time constraints that lead me to choose a place that had an online program I could do remotely, as well as place that allowed some flexibility so I could continue working while I was doing my master's program. And then within that set of options I really looked at the curriculum and tried to pick one that offered a set of classes that I was both interested in and it was applicable to what I was doing and fit together and gave that span of topics depth that I liked.

Similarly, Rashida, who holds a bachelor's in systems engineering, went on to work full time, but when it was time for her to pursue a master's she wanted to ensure that she did not have to give that up. Rashida went on to pursue a master's degree in engineering management; when asked why she choose the program she did her response was:

> Good question. Because, the <school name redacted>, the reason that I went there is because they offered all their courses at night. So, it allowed me to work during the day, temporary jobs. Even though it wasn't consistent employment, I did have jobs here and there that I could do during the day. They had all of these great courses at night.

Rohan had a similar path to Micah and Rashida. His first degree was in library science before migrating into computer science. His migration was not based on any particular passion he had for the field, but based on what was available to him or in his words what was 'convenient' for him. While there was an element of marketability, there was a stronger thread of convenience or availability in his choice.

> As far as from the past to this program, like I said before, it's not quite a win, but I'm doing this because it's a convenient opportunity really more than anything else. Maybe that's overstating it, but I think you understand what I'm saying. Convenience. I think computer science has obvious benefits in that it's highly marketable and it looks ... I'm saying same thing, same way it looks good on a resume. But since it's math-y and I like math stuff, it had an appeal to me, and once again, it was a complete distance program without a master's paper, and so that I knew I could fit it into my life.

These three participants illustrated that by the time it comes around for individuals to consider a graduate education a lot of them might already have fulltime – day jobs and are not willing to give that up to go back to school full time and as such they end up migrating into programs that match with their availabilities.

Discussion

In this study, there are several interesting findings regarding disciplinary migration between the bachelor's and master's degree. One of these is the extremely diverse range of people who migrate. The only demographic predictor of disciplinary migration is age, with older students more likely to migrate than younger ones. Even here, it may not be age per se but experience; as noted, those older students may have industry experience, which has been shown to have an impact on a student's graduate experience [e.g. 26, 31]. This is supported by the finding that disciplinary migrators report a greater degree of alignment between their work and their graduate program. Taken together, this implies that the students first termed "returners" by Peters & Daly [29] are likely to change disciplines. Further studies may illuminate the ways in which students' graduate school discipline and work experience interact. Some of these connections have been shown through the qualitative analysis, in which students talked about their choice of program; further investigation of the pathway from the undergraduate degree into the students' jobs, and then into the graduate programs.

Another interesting finding involves students' performance on the GRE, their undergraduate GPA, and their graduate GPA. Given that disciplinary migrators have a lower GPA than non-migrators, one might consider them to be, overall, weaker students, and expect their performance on the GRE to be lower than non-migrators. This was not the case; as noted, their performance on the GRE was no different. One might also hypothesize that they would show, overall, lower performance in their master's program, in particular because their original field of study may not provide the background material that a master's student in the new field would be expected to have. However, the opposite was seen. Taken together, these findings suggest that they are not, intrinsically, weaker students. Their higher performance in the new discipline may indicate that it is a better fit for their abilities and interests, similar to the change in major that can happen during undergraduate education as students explore their interests [3, 6].

The specific changes that participants made are also interesting. Many people changed into fields in the "Other" category. This field includes highly specialized fields, such as data science, which may not be available at the bachelor's level. This trend to become more specialized may also account for the 59% of mechanical engineering undergraduates in this study who went into other fields for their graduate degree, as mechanical engineering is a broadly based field of engineering that covers many different topics (e.g., thermal, fluids, machine design, dynamic systems and controls, and many others). Another common migration is into computer science. This change may be based partly on the availability of jobs in this area, as many industries and companies are in need of people who have this expertise. A full understanding of migration patterns, and the reasons behind them, would require a larger and more comprehensive study.

Conclusion

In this paper, we have studied the phenomenon of disciplinary migration, wherein students change their engineering discipline between their bachelor's and master's degree. We have shown that these students are quite common, that they change for a variety of reasons, and that they are able to be successful in their new disciplines, despite the possible challenges of learning any background material that was not included in their undergraduate education.

We have also shown that, while the majority of demographic characteristics are not predictors of migration, age and experience do predict and even motivate disciplinary migration. Understanding the factors that motivate migration is important, as it can assist universities in addressing specific academic needs or concerns [33], and contribute to their success.

Acknowledgement

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