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Perceived Self-Efficacy of Master's in Engineering Students Regarding Software Proficiency and Engineering Acumen

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Introduction

It is critical for engineers, as well as many other professions, that practitioners continue to learn after they complete their undergraduate education. Lifelong learning is a critical piece of professional development. One way among many that professionals may choose from is to pursue an advanced degree. In particular, a master's degree has been shown to have a positive impact on engineers' careers. Evidence shows that those with a master's degree tend to stay abreast of changes in technology as well as ways to adapt to new technology.[1] ABET has long encouraged continuing education.[2] In 2007, the National Science Foundation sponsored the 5XME workshop, which encouraged participants to discuss how to help US institutions train students to become the best engineers in the world. One of the workshop's recommendations was to establish the master's degree as an essential element of the field of engineering. "The masters degree should introduce engineering as a *profession*, and become the requirement for professional practice"[3] and as such the master's degree can be seen as a benchmark of the professional engineer.

While a master's degree has an effect on a professional's further opportunities, one's background and skills as well as interests and capabilities also influence professional development. For younger students, it might be thought that their skill with software could be greater than that of older students returning to the classroom[4, 5, 6]. The notion of the "digital native"[4] has taken hold in the imaginations and classrooms of educators across the country. This notion may have implications regarding facility with computer-aided work in industry, as well as one's own perceptions about software use and skill. The older student has not grown up with technology. Another point of interest is the amount of time spent in industry before returning to university and how that bears on master's level academic learning. We define those learners who have spent at least five years in industry before returning to university to pursue a master's degree as returners[7,10]. In contrast, direct-pathway students are those who have chosen to remain in the university environment or to return to university less than five years after their undergraduate education has been completed. This leads to the two key questions addressed in this paper, related to this potential tradeoff between computer skills and broader professional skills:

- Do direct pathway students, who may be younger, perceive themselves as having greater efficacy with software than returners do?
- Do returners, who are more experienced engineering graduate students, rate their self-efficacy higher in engineering skills than direct pathway students?

A five-year gap differentiating returners from direct-pathway students may seem arbitrary, but it is based in part on the fact that practicing engineers are encouraged to wait until they have completed at least four years in industry before attempting the Professional Engineer (PE) examination. We wanted to capture the experiences of students who would be eligible for this examination and/or decided to return to graduate school after this interval. Studies have demonstrated that returners face unique challenges.[7, 8, 9, 10] However, scholarship has not focused on how returners' prior experiences affect their learning in the classroom and whether it may differ from that of direct pathway students.

The relevant survey questions for this study are:

1. Do you use the same software in your Master's program as you do/did at work?
2. The software is used the exactly the same/the same with minor variation/similarly/we mostly used different functions/we used completely different functions
3. Take a look at the software categories in the table below. How would you describe your level of expertise? If you have formal certification, please check the box in that line of software category as well.
4. How confident are you in your ability to... (various engineering skills)

Literature and Conceptual Framework

One of the ways this study can be understood best is to view the two groups of students, direct pathway and returners, as two groups with different preparation for the graduate degree in engineering. Students who have spent time in industry practicing engineering may be thought to have greater skill in engineering than students who matriculate directly into a graduate program, just because they have not spent as much time in the field, applying what they learned. Recently there has been a focus on engineers and the skills they bring to the workplace. Graduating engineers need to have the attributes necessary to engage in the work from the first day of their hire.[11] It is also known that experience is an important way to grow expertise.[12] However, what is not so clear is how work experience affects the learning in a master's-level engineering course. Some work has begun in this area,[9, 10] but this is only a start, and focuses more on the PhD student. The research presented here is designed to help understand the different skills, namely software use, and perceived self-efficacy of direct pathway and returner students.

There is to date not enough research done in the area of differentiating the needs and skills of these two groups of learners, although they will study together in the same courses. Learning does occur in the workplace. It is informative to understand workplace learning, informal learning, and tacit knowledge. It is an accepted rule of thumb that "10 years or 10,000 hours"[13, 14] of deliberate practice[15] helps one achieve expertise. As well, professional engineer (PE) licensure is only available to engineers once they have completed at least four years in their field. We wanted to compare the student who came directly from an undergraduate degree to a master's level program with that of students who had spent at least five years in industry before returning to the classroom. Studies of expertise can be found in abundance in the literature. [12, 13, 14, 16] There is evidence as well that expertise is context-specific.[17] Research by Schön shows that experts think about the same situation or problem differently than novices.[15] There seem to be skills intrinsic to each type of work, and practitioners cannot adequately explain their thought processes to others.[18] The same holds true with other professions, and is arguably the rationale behind the years of deliberate practice experienced by medical doctors on their way to becoming independent physicians among other professions.

The work of Eraut has increased understanding of workplace learning. He and colleagues have investigated the notion of informal learning in the workplace and its importance in creating competent workers.[19] Lave has also researched situated learning and communities of practice to show that these learning environments, while not necessarily promoted in the classroom, are nevertheless the ways in which we learn at work.[20] There is evidence that the learning from the practice of one's work can be lasting and deep. Studies also show that Bandura's social learning theory has merit in understanding how individuals learn at work, as well their perceived self-efficacy.[21] Many engineering programs regularly offer students a chance to work in their chosen field before graduation in order to learn more in a practical application setting. This practice can be traced to the apprenticeship model and is beneficial to students. If time in the workforce does have an impact on engineering acumen, do returning engineering graduate students as a group think they are good at what they do, and does the difference in the number of years on the job make a difference in this self assessment?

Our research is concerned with the different levels of skill, experience, and understanding that domestic master's in engineering students possess as well as how they perceive their efficacy. We relied on adult learning theory[10, 21] and self-efficacy theory[22, 23, 24, 25] to help us frame the questions for our respondents and our understanding of their experience as master's students.

Methodology

The data for this research was collected via anonymous survey, administered over the web using Qualtrics. Respondents were asked questions about whether the software that was used in their coursework was the same as that used in their industry experience and what certifications, if any, they had obtained. We also asked self-efficacy questions about the software they used. We then asked self-efficacy questions about engineering skills. The self-efficacy questions about engineering skills were taken from Brennan, Hugo, & Gu[26], while the self-efficacy questions about software were developed for this survey. The survey was subjected to three iterations of piloting with multiple participants in order to ensure that it would elicit the information desired.

Participants

The participants for this study are master's in engineering students. Demographic information is in Table 1.

Table 1: Demographic Information

Direct Pathway	211
Returner	89
Median Age	25
Ethnicity	
American Indian	5
Asian	49
African American	11
Hispanic/Latino/a	18
White	226
Other	4
Unanswered	5

One of the challenges in conducting this study was in collecting sufficient responses, particularly for the returner population. Our survey had 330 respondents, with 300 of them completing the entire survey. We had intended to have an equal mix of returners and direct pathway students, but reaching a sufficient number of returners was difficult. Furthermore, the nature of the master's degree student was not clear-cut in some cases, as there were a number of people who mixed part-time or full time work with part-time or full-time school, took courses between degrees, and followed a variety of different pathways. For our true returners, those who left school and never went back until more than five years after they obtained their undergraduate degree, there were only 71 respondents. We chose to include some respondents as returners, even though they may have attended classes in the interim between their undergraduate and graduate courses. This was because their enrollment was not continuous.

The study was limited to domestic students because of the large number of variables that are added when international students are included, such as language proficiency and cultural issues that affect learning. The aim of the recruitment of these respondents was to obtain an equal amount of returners and direct pathway students. The survey was piloted with both returner and direct pathway domestic master's in engineering students. A professional analyst also examined the survey for validity. Queries for participants were sent to over 150 graduate schools of engineering in thirty states in the US. Those schools that agreed to send on requests for participants in our study were then given information for students to contact us. Students were given an anonymous link to the survey. Responses were collected over a period of approximately four months.

There are approximately 137,000 master's in engineering students in the US.[27] However, many of them have obtained their undergraduate degrees at foreign universities. While ABET has indicators in place to allow for some comparisons, the experiences of these students are difficult to compare with those of the students who matriculated from American institutions. Aside from issues of curriculum, there are language issues in some cases and cultural issues; in addition to the way these issues interact with the educational environment, the working environment in foreign countries may be very different from the workplace in the United States. For these reasons, this population was not included in the study, which decreased the size of the available survey population. Furthermore, returner status is not a tracked demographic for foreign or domestic students, so it is difficult to even know how large this population might be.

Questions

In the survey, we asked students whether the software they used in their courses was the same as at work. If they said yes, we asked the degree to which the software use was the same. Then we asked the students how they perceived their ability to use the software—how good did they perceive their skill to be? Lastly, we asked a set of more general self-efficacy questions regarding their engineering skills—how did they perceive their ability?

As previously stated, the relevant survey questions were:

1. Do you use the same software in your Master's program as you do/did at work?
2. The software is used the exactly the same/the same with minor variation/similarly/we mostly used different functions/we used completely different functions
3. Take a look at the software categories in the table below. How would you describe your level of expertise? If you have formal certification, please check the box in that line of software category as well.
4. How confident are you in your ability to... (various engineering skills)

The software categories in this question were:

- Programming Tools
- Mathematical and Simulation
- Office Applications
- Statistical Analysis
- CAD Software
- Controls and Data Acquisition
- Revision Control
- Collaboration Software

The engineering skills were:

- Apply your engineering knowledge and skills to solve a real-world problem.
- Apply an appropriate engineering technique or tool to accomplish a task.
- Review your team's strengths and weaknesses and tell others where the team might need help.
- Identify processes in your project to ensure protection of the public and the public interest
- Use your technical knowledge to participate in a design discussion.
- Synthesize information to reach conclusions that are supported by data and needs.
- Identify the safety concerns that pertain to a project that you are working on.
- Make assumptions that successfully simplify a complex problem to make it easier to work with.
- Use mathematics to describe and solve engineering problems.
- Interpret a formal technical drawing in your engineering discipline.
- Apply technical, social, and environmental criteria to guide tradeoffs between design alternatives.
- Analyze the tradeoffs between alternative design approaches and select the one that is best for your project.
- Use technical literature or other information sources to fill a gap in your knowledge.
- Work with others to establish project objectives when different project tasks must be completed.
- Identify an ethical dilemma when it occurs in a project. Identify your professional responsibilities within a large engineering project.

Results

Responses to the first software use question, *Do you use the same software in your Master's program as you do/did at work?,* are presented in Table 2. It can be noted that not all participants answered this question; however, of those who did answer, very similar percentages of returners and direct pathway students reported that the same software was used in their Master's program as they had or were using at work, with just over 40% reporting yes and the remainder saying no.

Table 2: Tabulated statistics of software use responses

Do you use the same software in your Master's program as you do/did at work?				
	No	Yes	Missing	All
Direct Pathway	105	72	34	177
	59.32%	40.68%	*	100%
Returner	48	33	8	81
	59.26%	40.74%	*	100%
All	153	105	*	258
	59.30%	40.70%	*	100%

Table 3 shows how software is used in the classroom compared to how it is used on the job. Again, there were some survey respondents who did not answer this question; of those who did, most indicated that the software was used in a similar way or the same way as at work; very few respondents, of either direct pathway or the returner population, indicated that the software was used in a mostly different or totally different way than they had used it at work.

Table 3: Tabulated responses regarding software use similarity

The software [at school] is used							
	The same way as I do/did at work	The same with minor variation	Similarly. We use some different functions of the software	We mostly use different functions of the software	We use the software in a completely different way than I do/did at work	Missing	All
Direct Pathway	19	20	31	2	0	139	72
	26.39%	27.78%	43.06%	2.78%	0%	*	100
Returner	8	12	11	0	2	56	33
	24.24%	36.36%	33.33%	0%	6.06%	*	100
All	27	32	42	2	2	*	105
	25.71%	30.48%	40%	1.90%	1.90%	*	100

Figure 1 shows the interval of perceived efficacy with software and types used by these students. Students were asked about some types of software programs that they might be using – programming software, mathematical software, office software, statistical software, CAD software, controls software, version control software, and collaboration software, and about their level of proficiency with that software. No significant differences were found for the two populations, although it can be seen that the standard deviation of the responses was larger for returners than for direct pathway students. Students' highest level of perceived efficacy was for office software, which was significantly higher than their perceived efficacy with other types of software. The rating was a 1-5 scale, 5 being highest confidence level, and 1 being the lowest.

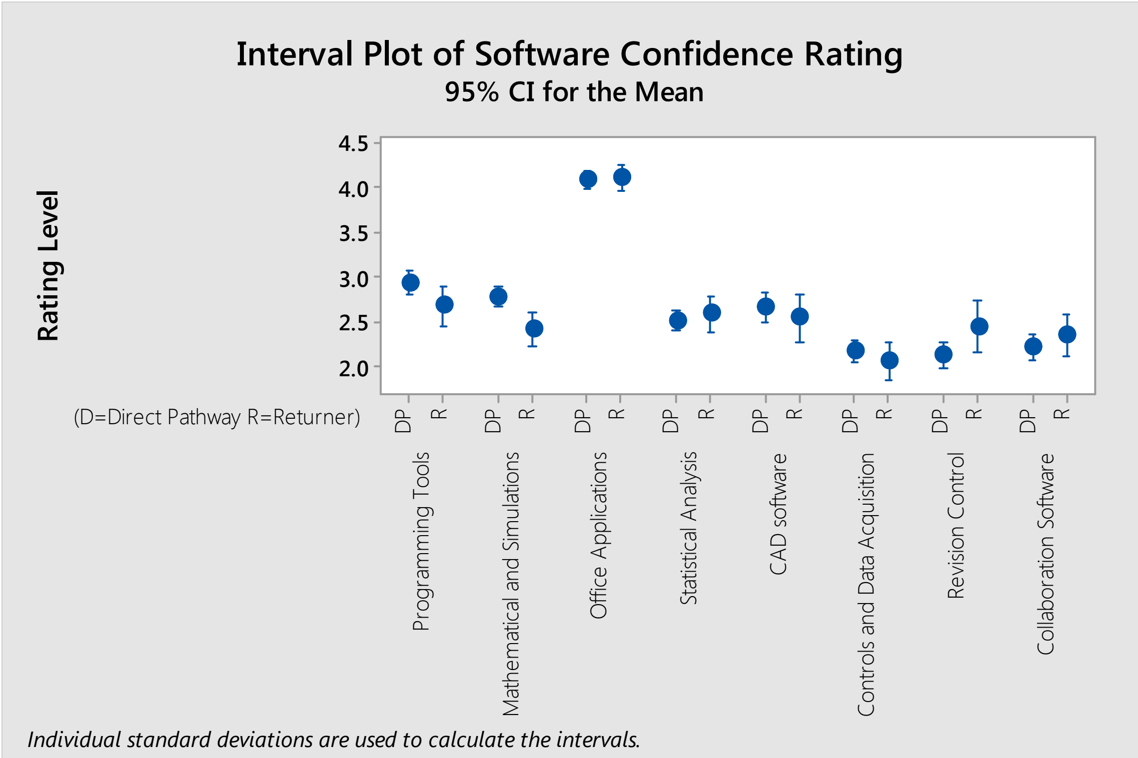


Figure 1: Perceived Efficacy with Software Types

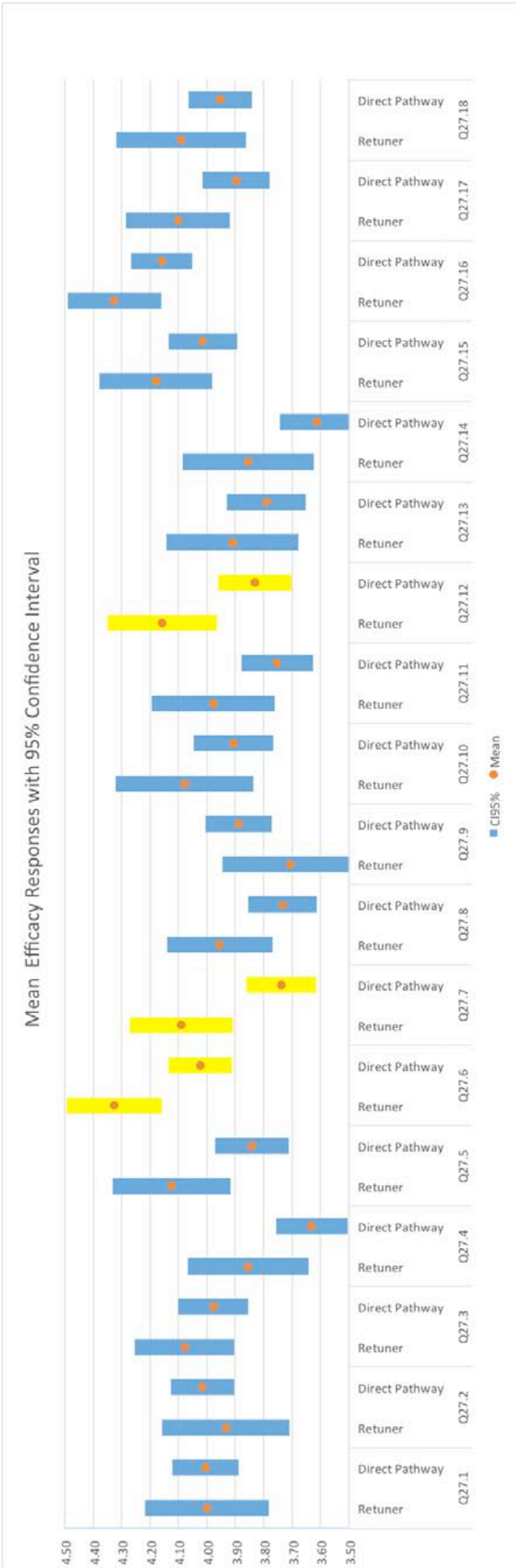
Table 4 shows the number of participants who reported formal certification in some form of software. CAD software had the largest number of formally certified respondents. Four of those people specified that their CAD certification is in SolidWorks (Certified SolidWorks Associate), and one person indicated s/he was an AutoCAD Certified Professional. In the "other" category, participants reported their software experience as critical thinking in problems, FEA Tools, geology specific software, Hardware Design Tools, Process Design, and Proprietary software packages. Each response occurred once, with the exception of geology specific software, which was reported by one returner and one direct pathway student.

Table 4: Formal Certification in Software

Software Category	**Number of Participants**	
	Returners	**Direct Pathway**
Programming Tools	1	2
Mathematical and System Simulation Tools	1	2
Office Applications	2	0
CAD Software	2	13
Controls and Data Acquisition	0	1
Other	1	5
Total	7	23

Figure 2 shows the responses of students regarding the practice of engineering along with a confidence level for each. In this question, students were asked about their level of self-efficacy in completing some engineering tasks; the specific tasks are delineated beside the table. For most of the tasks, the data did not show statistically significant differences between the responses of returners and direct pathway students, although again, the standard deviations of the returners' responses were larger. There were three tasks for which differences were statistically significant: these were *Synthesize information to reach conclusions that are supported by data and needs*, *Identify the safety concerns that pertain to a project that you are working on*, and *Analyze the tradeoffs between alternative design approaches and select the one that is best for your project*. In all three cases, returners had a higher level of confidence in their abilities.

The two items with the highest ratings were, *Use your technical knowledge to participate in a design discussion* and *Work with others to establish project objectives when different project tasks must be completed*. For these items, there were no statistically significant differences between returners and direct pathway students.



18. Identify your professional responsibilities within a large engineering project.

17. Identify an ethical dilemma when it occurs in a project.

16. Work with others to establish project objectives when different project tasks must be completed.

15. Use technical literature or other information sources to fill a gap in your knowledge.

14. Identify and plan for risks in an engineering project.

13. Prepare a sketch of a design concept that is understood by your colleagues.

12. Analyze the tradeoffs between alternative design approaches and select the one that is best for your project.

11. Apply technical, social, and environmental criteria to guide tradeoffs between design alternatives.

10. Interpret a formal technical drawing in your engineering discipline.

9. Use mathematics to describe and solve engineering problems.

8. Make assumptions that successfully simplify a complex problem to make it easier to work with.

7. Identify the safety concerns that pertain to a project that you are working on.

6. Synthesize information to reach conclusions that are supported by data and needs.

5. Use your technical knowledge to participate in a design discussion.

4. Identify processes in your project to ensure protection of the public and the public interest.

3. Review your team's strengths and weaknesses and tell others where the team might need help.

2. Apply an appropriate engineering technique or tool to accomplish a task.

1. Apply your engineering knowledge and skills to solve a real-world problem.

Figure 2: self-efficacy in engineering skills

Discussion

The findings in this study showed that direct pathway and returners have much the same experience with software in school and in industry. This seems to show that schools are using the same software that is used in industry to prepare students for the engineering applications they will actually use. There were a small number of students who reported a formal certification. From 330 respondents, there were only 30 who reported such a certification – 23 direct pathway students, and seven returners.

In looking at the software usage among the survey respondents, it was interesting to note that there were no statistically significant differences between the returner and direct pathway populations. In both cases, whatever work experience they had obtained – full-time work, co-op assignments, summer internships, or other part-time work – used the same software in basically the same ways in similar proportions. In those approximately 60% of cases where the same type of software was not used, it is not yet known what software types were different, or why that might be; questions on these topics may be included in the interview phase of the study, in order to probe more deeply into the ways in which software tools influence students' learning. The fact that students' confidence level was highest with office software is not surprising, as it is one of the most commonly used types of software. Engineers in some types of jobs may use CAD extensively, for example, while others do not use it at all; however, the majority of engineers will need to communicate in the form of some type of written documents and/or presentations, and therefore will need to use some form of office software.

While it was not statistically significant, there was a larger difference in confidence with mathematics software than with other types of software, and given a larger population it is possible that this difference may be significant. This seems to be an area where returners feel less self-efficacy than direct-pathway students. This may be because the study of pure mathematics and the use of software in mathematical calculations are more recent for the direct pathway student. Returners may not have as much recent experience with some of the theoretical mathematics, as was also seen in an earlier study[7]. This is also something that may be covered in the interview stage of the project.

The differences in the size of standard deviations, with returners showing a larger standard deviation on their confidence with software than direct pathway students, could be attributed to the different types of jobs that they hold in industry. Students in a given field of engineering can be expected to see similar software in their undergraduate curriculum, and to acquire at least a minimal standard of proficiency; however, as practitioners use some types of software tools extensively but not others, their confidence will change – increasing for those tools they use often, and decreasing for those that they have not used extensively.

A similar explanation may account for the larger standard deviation in returners' self-efficacy ratings on engineering skills, as compared to direct pathway students. In that case, as noted, there were three engineering skills for which returners were significantly more confident. These skills, as previously stated, were: *Synthesize information to reach conclusions that are supported by data and needs, Identify the safety concerns that pertain to a project that you are working on*, and *Analyze the tradeoffs between alternative design approaches and select the one that is best for your project*. All of these are critical skills in the workplace. Students may not have had extensive experience with these in school. Synthesis and analysis tasks are definitely part of

Bloom's Taxonomy, and engineering programs include these, particularly in upper-level courses; however, a classroom setting is quite different from the workplace, and tasks in the workplace may be more open-ended than in a class. These terms may, in fact, be interpreted somewhat differently in different environments. In the workplace, the analysis task might be called discernment. Engineers may have a number of conversations regarding the one best fit for a particular application or machine. They need to be able to decide which design is the best for the project. This confidence in one's ability to discern best fit is gained by experience with success in this area. In regard to safety, safety concerns are paramount in industry, while they may not be extensively covered in engineering coursework. Certainly, safety is emphasized in lab classes, and a capstone design project may include safety as a criterion; but the issues of meeting industry-specific safety standards, machine guarding, and OSHA requirements are much more prevalent in industry than in any undergraduate courses.

Implications

Returners and direct pathway students do not differ in their self-perception of their ability to utilize computer applications. Since it is a commonly held belief that there is a great difference between older and younger students—"digital natives and digital immigrants[4]"—perhaps it is encouraging that the students themselves return similar self-efficacy ratings. The rationale, seen in the literature, is that younger students are fundamentally different in terms of software use. Our results did not show this. It seems that, with the exception of a few areas, learners' self-efficacy is similar. We do not know how accurate that self-perception is, but it bears investigation. As well, the spread of returners' level of self-efficacy were overall larger than returners. This could have come from the lack of more respondents. However, it can also be seen to represent the notion that the more we know, the more we realize we need to learn.

Conclusion

In this paper, we analyzed results of a sub-set of questions on a large, comprehensive survey of domestic master's students in engineering with a range of experiences between the completion of their undergraduate degree and the start of their master's degree. These questions focused specifically on their software usage and engineering skills, and pointed to some of the ways in which learning in the classroom is linked to experience in the workplace. There are still several unanswered questions resulting from the analysis of this survey, and many other survey questions that can be analyzed. As work continues on this project, responses to the remaining majority of the survey questions will be analyzed. In addition, the interview phase of the project will be designed, piloted, and deployed. Through this work, we plan to delve into the ways that graduate returners deal with information learned and forgotten in their undergraduate courses. We also plan to explore the decision to return to graduate school, and whether direct pathway and returners incorporate new knowledge differently. Other questions to be investigated may include online course desirability and flexibility of choices in course delivery. Answers to these questions will allow universities to better serve their existing masters' students of all types, leverage the experiences of the returners within their graduate population, and better attract students into programs that will suit their needs.

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