How Important is High-School Computing Experience for First-Year Engineering Student Success?

Amber Kemppainen, Mary Fraley, Amy Hamlin, Gretchen Hein
Engineering Fundamentals
Michigan Technological University
Houghton, MI 49931
amber@mtu.edu

***Abstract*— First-year engineering students enter our university with differing experiences using computers and technology. This affects the classroom dynamic especially with large differences between students. With this in mind, faculty must address the following questions when planning their course: Where should the faculty focus their time? Do they focus on bringing everyone to a specific level? Do they teach to the average student and hope the less experienced keep up and the more experienced are not bored? The first step to answering these questions is to determine the distribution of experience. To assess this, first-year engineering students at Michigan Technological University were given the National Assessment of Education Progress (NAEP) Computer Access and Familiarity Survey (Grade 12) during their first week of classes. The NAEP survey measures access to and familiarity with technology. The survey was modified to measure the familiarity with computing tasks students use in their first engineering courses. This paper will focus on determining: how much exposure to computers and technology have our students had, what exactly is the depth and breadth of the skills they enter the university with, and are there any factors within access or familiarity that impact success in the first-year engineering courses?**

Keywords— computing, access, student success, engineering

I. Introduction

Engineering students enter college with a variety of technical abilities which include technical communication, math/science skills, and computing/technology skills. They can enhance their confidence in these topics and subsequent performance.

Much work across the nation is being done to address technical skills and performance within the K-12 system. At Michigan Technological University, a Herbert H. and Grace A. Dow Foundation grant was awarded to develop an integrated science curriculum for sixth through eighth grade students. The curriculum will be aligned with the Michigan and national science standards. The materials developed by the program use science and engineering concepts and applications to investigate contemporary problems. [1] In another program, research has been completed to map the Common Core State Standards and Next Generation Science Standards into a university first-year engineering program. The different standards (i.e. Michigan, National and Common Core State Standards) organize the materials differently which makes it makes it difficult to map incoming skills. This makes it difficult to determine what skills students have when they enter an engineering program. Therefore, a survey where entering first-year engineering students report their background skills would be useful.

To further complicate matters, there is no universal manner to introduce college students to the field of engineering because each university customizes material to meet the needs of their programs. [2] A First Year Engineering Experience (FYEE) Conference workshop was held where 28 courses were mapped into a classification system. The major course categories were: Communication, Design, Global Interest, Engineering Specific Technology/Tools, Math Skills, Academic Success, Engineering Profession, and Latent Curriculum/Professional Skills. [3] Once mapping is completed, analyses will be performed to assess how students both perceive their abilities based on past experiences and performance, and what skills they actually have when they enter college.

Another study investigated student experiences in "computational engineering practices" and the number of prior computing courses to see how their past experiences and performance correlated to their actual performance in the university course. The researchers found that as the number of meaningful computing experiences occurred, the more students were engaged in subsequent computing exercises. [4] Students were not only using technology in their classes, but they were online much of the time. This study focused on the habits of millennials, where 56% of engineering students reported that they were online "most of the time". Not only are the students online, but they are frequently accessing information with other students. Although students reported that they were texting, e-mailing and web browsing during academic activities, they were not commonly "chatting". [5] This research focused on the tools students were using and not on their academic abilities or on how that use affected their academic performance.

With a lack of consistency between K-12 standards, there is no method to determine an incoming student's technical skill history or the skills they are using. Due to the wide range of topics covered in first-year engineering programs, a

survey to determine the incoming student skill set would allow faculty to help students build upon their existing skills. This study investigated how the use of computer tools prior to college impacted student performance and confidence in ENG1101. At Michigan Tech, engineering students complete a common first-year program. The students who are calculus-ready take a two course sequence (ENG1101 followed by ENG1102). Students who are not calculus-ready complete a three course sequence (ENG1001, ENG1100 and ENG1102).

II. Methods

To determine student access to and familiarity with computers and computational tools, students from Michigan Technological University's first-year engineering course, ENG1101, were asked to complete a survey at the beginning of the school year. The survey was administered through Survey Monkey®. The survey was based on the National Assessment of Educational Progress (NAEP) Computer Access and Familiarity Survey (Grade 12). [6] The survey included questions to assess 1) student access to technology and 2) student familiarity with technology. Student access to technology included school and home use of computers, tablets, and smart devices. Technology familiarity was measured by the frequency and variety of tasks completed on the computer. Some questions were changed and/or deleted when they did not pertain to university students. Additional questions were added to measure the familiarity with computing tasks students would be using in their engineering courses. For example, we included questions specific to experiences with spreadsheet and programming tasks. This was done with permission from NAEP. The Computer Access and Familiarity Survey can be accessed at https://www.surveymonkey.com/r/TV3MJGZ. Our sample was taken from ten of the fifteen sections of ENG1101.

The survey data were analyzed to determine: 1) How much exposure to computers and technology have the students had? 2) What is the depth and breadth of skills students enter the university with? 3) What are the factors (either within access or familiarity) that impact their success in the first-year engineering courses? Student success was measured using scores from an Excel lab practical, a MATLAB lab practical, and the overall course grade.

III. Student Demographics

Of the 887 students enrolled in ENG1101 in fall 2015, 764 students were included in this study (572 male; 185 female; 8 did not answer). Of the remaining 123 students, some chose not to complete the survey and some completed the survey multiple times with conflicting answers and were removed from the study. The majors of these students were recorded at the beginning of the semester. There were six students that were planning on earning two degrees within engineering and were included in the totals for both majors. A majority of these students are confident that they will complete their major: 111 students or 14.5% were completely confident; 422 or 55.2% were very confident; 206 or 27.0% were moderately confident; 19 or 2.5% were slightly confident; and 6 or 0.8% were not at all confident. While 99 (13%) students have not considered other majors in the past, the majority have considered other majors 413 (54%) within engineering; 54 (7.1%) considered other majors within business; 161 (21.1%) considered majors in math or science, and 36 (4.7%) have considered other majors in humanities or social sciences.

IV. Student Access

A number of survey questions pertained to students' access to computers and other digital devices. Home computer access was high, with less than 1% of the students indicating that they live in a home without a computer or laptop, and 92.5% percent of the students reporting that they have a laptop or desktop computer for their own personal use. In comparison, Zhang et al. report that less 7% of the eighth-grade public school students live in a home without access to a computer. [7] Additionally, the students who participated in our study were well connected, with more than 99% of the students reporting they have access to Wi-Fi or some internet connection, and a smart phone for their use.

V. Student Familiarity

Students have been using digital devices for much of their lives. As shown in Fig. 1, students reported using computers at a much earlier age than smartphones or tablets, with approximately 70% of the students using a computer prior to fourth grade, while only a few students first used a tablet or smartphone during the same period.

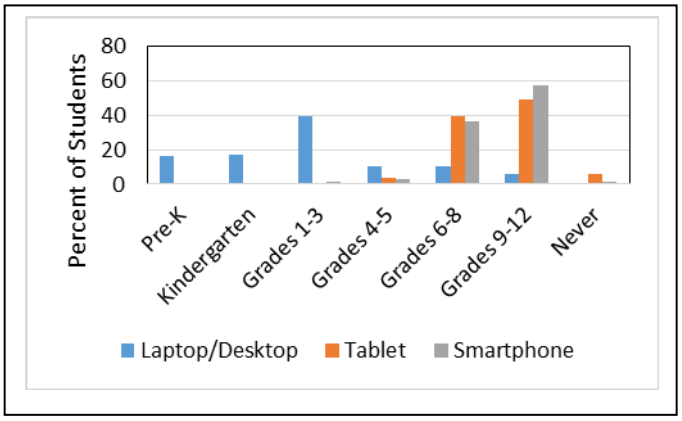

Fig. 1. First reported student use of digital devices.

Students reported that they use a computer more often for schoolwork than a tablet prior to coming to Michigan Tech. More than 70% of the students reported that they spent at least one hour per weekday using a computer for schoolwork including homework, while only 11% reported using a tablet for more than an hour a day for schoolwork. Forty-six percent of students reported having access to computers in most of their classrooms prior to coming to Michigan Tech and 17% of the students reported that most of their teachers required the use of computers in their classrooms. Nearly 15% of the students had a computer assigned to them for their sole use

either at school or for them to take home and an additional 10% of the students had a tablet assigned to them. A few students (n=9) had both a computer and tablet assigned to them.

Students reported being taught a variety of computer skills prior to coming to Michigan Tech. Nearly all students (>98%) were taught to use computers for school writing activities (writing and editing using a computer, searching for information on the internet) and to create presentations, while a smaller number of students (36%) were taught to use computers for general writing activities such as writing and maintaining websites or blogs. A large percent of students were taught to create a spreadsheet (84%) and create graphs or charts using a computer (80%), however, a smaller number of students (56%) reported learning to write equations in a spreadsheet. An even smaller percent of students (20-23%) were taught to write programs or apps and run simulations.

TABLE I. FREQUENCY OF USING COMPUTERS FOR A VARIETY OF TASKS

Task	Never	A few times	Once every few weeks	About once a week	More than once a week
Write a short paper (less than a page)	3.9	19.4	30.6	34.3	11.5
Write a paper longer than a page	1.6	18.6	51.6	22.8	4.6
Write a paper where you described data from a table or graph	16.9	42.9	26.3	10.7	2.6
Search Internet for a school project	2.0	12.7	22.9	27.7	34.4
Practice things in mathematics that you were having trouble learning	27.7	27.6	13.4	15.1	15.3
Practice things in reading that you were having trouble learning	41.0	31.0	12.6	8.4	6.2
Take a test	16.8	33.1	22.1	17.9	9.8
Create a map	78.1	17.0	3.4	0.5	0.5
Work on a website or blog that you maintain	71.3	15.1	6.0	3.9	3.3
Create a multimedia presentation on your own	8.4	37.1	39.1	11.4	2.9
Work collaboratively with a team of students to create a multimedia presentation	9.6	41.9	35.5	9.3	3.4
Create a graph or chart	12.7	37.8	30.0	14.5	4.6
Use a spreadsheet to perform calculations	41.5	33.6	14.3	6.3	3.5
Write a computer program or app	80.1	9.0	3.7	3.3	3.7
Run a simulation	72.8	17.3	5.1	3.1	1.4

A comparison of the frequency that students used computers to complete a variety of tasks during their last school year is shown in Table I. Students reported that they frequently used computers for writing tasks, 46% said they wrote a short paper (less than a page) at least once a week, and more than 50% said they wrote a paper longer than a page for school once every few weeks. Students were less often asked to write a paper where they described data from a table or a graph (approximately 60% report doing this a few times or never doing this). Students were asked to create a presentation either on their own or in a group (35-40% report doing this every few weeks, with 12-13% doing this more frequently, about once a week or more than once a week). It was less common for students to use a spreadsheet to perform calculations (41% never did this, 34% reported doing this a few times), run simulations (73% never did this, 17% did this a few times), and write a computer program (80% never did this, 9% did this a few times). These are the skills we focus on building in the first-year engineering program at Michigan Tech.

TABLE II. COMPUTER SELF-EFFICACY

Task	Definitely can't	Probably can't	Probably can	Definitely can
Write sentences and paragraphs using a computer	0.3	0.1	4.5	95.0
Edit text using a computer	0.3	0.4	8.9	90.1
Use a touchscreen on a computer, tablet, or smartphone	0.1	0	10.1	89.3
Look up the meaning of a word using a computer	0.3	0	3.0	96.0
Draw a picture using a computer	1.3	10.6	47.8	40.1
View or download digital media	0.5	1.3	22.3	75.4
Create a presentation using a computer	0.3	0.3	10.2	88.6
Create a spreadsheet using a computer	1.3	6.2	34.4	57.7
Install new software or apps	1.3	4.8	30.8	62.8
Participate in online discussions, forums, social networking sites, or virtual communities	0.4	0.9	30.8	67.7
Maintain a website or blog	7.5	23.2	48.7	20.3
Search for information on the Internet	0.4	0.4	5.2	93.6
Run simulations using a computer	10.5	24.2	49.2	15.7
Create a graph or chart using a computer	1.2	6.4	38.4	53.7
Write a computer program or app	30.5	32.01	27.0	9.3
Troubleshoot a problem with a computer	9.4	19.9	43.7	26.3
Figure out how to use new functions of a digital device that I am not yet familiar with	2.4	7.7	57.3	32.2

As shown in Table II, several questions on the survey asked students if they felt they could complete a given computing task. We used these questions to calculate what we are calling the students' computer self-efficacy. This computer

self-efficacy was high for the tasks related to writing for school, with 90-96% of students responding that they could definitely write sentences, edit text, look up the meaning of a word, and search for information on the internet. Students were very confident in their ability to create a presentation (89% responded I definitely can). Students were confident in their ability to create a spreadsheet (58% definitely can, 34% probably can) and create a graph or chart (54% definitely can, 38% probably can). Students had less confidence in their ability to run simulations (16% definitely can, 49% probably can) and write computer programs (9% definitely can, 27% probably can, 32 probably can't, 30% definitely can't).

STUDENT PERFORMANCE

After determining that most students have access to computers, their level of familiarity with computing tasks, and their computational self-efficacy, we wanted to assess whether the differences in these quantities affect their overall performance in the first-year engineering classroom. We started our analysis by running a simple correlation to see if any of the questions related to either access or familiarity were strongly correlated with performance on either the spreadsheet or programming lab practical or final grade. Only those students who completed the survey and both lab practicals were analyzed (N = 479). However, while there were some statistically significant results, with weak correlations, none of these results were expected. As found by Hagan and Markham [8], we expected students with more programming experience to perform better on the programming lab practical and similarly those with more experience using spreadsheets would perform better on the spreadsheet lab practical. In reality, the frequency of using a spreadsheet in the past year was not correlated significantly with the Excel spreadsheet lab practical ($r=0.016$, $p=0.735$). Nor was the frequency of writing programs ($r=0.058$, $p=0.203$) or running a simulation ($r=-0.041$, $p=0.376$) correlated significantly with the MATLAB lab practical. The largest correlation ($r=0.222$, $p=0.000$) was between the Excel Lab Practical and if the student was taught how to edit text using a computer, not their experience with spreadsheets or programming.

As these results were unexpected, they need further investigation. Two major concepts were chosen for this analysis. First, a student's self-reported knowledge, as measured on a 4 point Likert scale ranging from "I hardly know anything at all" to "I know a lot." The second was their computational self-efficacy, which was calculated by transforming the data in Table II to a scale (e.g., Definitely can't =0, Definitely can =3) and taking the sum of these values. Looking at these two factors in particular, we looked at the differences in performance with students with high vs. low knowledge and computational self-efficacy.

The majority of the skills taught prior to attending Michigan Tech did correlate significantly with the students' self-reported knowledge of computers ($p=0.000$). These were among the strongest correlations that appeared in this analysis: maintaining a website ($r=0.262$), writing a computer program ($r=0.306$), and troubleshooting computer problems ($r=0.463$).. Using a one-way ANOVA with Bonferroni post-hoc test, students that had more experience with computers were found to have a higher computational self-efficacy ($r=0.514$, $p=0.000$), and students with less knowledge had significantly lower self-efficacy ($p<0.005$) than those with more knowledge. This is apparent in all levels of knowledge and not just the extreme ends of the spectrum (I hardly know anything at all vs. I know a lot.). A median-split was performed on the computational self-efficacy to see if there are significant differences in performance with "high vs low" computational self-efficacy, but no significant differences in performance were detected. Therefore, it appears that all students regardless of their previous computing experience and computing self-efficacy perform equally well on the computational metrics. Again, these results seem counter-intuitive, as the student with higher self-efficacy and knowledge should be expected to perform at a higher level. One way of interpreting this is that the first-year program is able to prepare students to meet the computing requirements necessary for success regardless of previous computing experience.

VI. CONCLUSIONS

This study investigated the effects of prior computer access and familiarity with computational tasks on student performance in a first-year engineering program. To summarize, almost all students had access to computers and the internet at home (>99%). Students had been taught, had used, and were completely confident in their ability to use computers for writing activities for school and presentations. Students were familiar with using spreadsheets and creating graphs or charts and were confident in their ability to complete these tasks. However, a much smaller number of students had experience with the computational skills taught in the first-year engineering courses including creating equations in spreadsheets, writing about data contained in a table or graph, and writing a computer program. There did appear to be significant differences in the computational self-efficacy in our incoming students with regard to their computational knowledge. Despite these differences, it appeared that the students perform equally on our first-year engineering computational metrics for ENG1101. In other words, those students with lower technical skills were not at a disadvantage in their first engineering course.

In the future, further analysis can be completed to determine if the results for ENG1101 are the similar to our ENG1001 population. Additionally, we will investigate if background computer skills and confidence differs with engineering major.

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