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Finding what matters: a deeper look into factors that affect student success in first year computer science courses

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Abstract

This Complete Research Paper focuses on factors that influence a student's rate of success in a 100-level computer science course. Computer science education has evolved significantly in recent years as an effort to expand access and to encourage students to pursue careers in related technologies. Although before the 21st century, it might have been uncommon to see a student at the K-12 level write a program simple enough to output "Hello World", today students are creating algorithms that tell stories, interact with a user through a mobile app or control a robot to complete a series of tasks. With these new opportunities, especially in secondary education, it raises the question as to how this experience translates to success at the collegiate level, particularly in a 100-level computer science course. In addition, how do factors such as race, gender and highest achieved math level affect a student's success? This case study acts as a follow up to a previous study that focused on Michigan high school graduates pursuing an engineering degree at a regional university and enrolled in a semester long 100-level applied programming course offered by the engineering department. The primary method employed for this study was survey research. As with the previous study, participants were asked to self-report their prior computer science experience such as course or activity as well as the types of programming languages they may have worked with. In addition, the new study allowed participants to provide demographic information such as geographic region of residence, race, gender, and math enrollment. The study was also expanded to include participants enrolled in an equivalent 100-level course offered through the university's computer science department as well as a new "stretch" version of the course offered by the engineering department. The results were analyzed using logistic regression to determine if any of the factors of interest had an influence on a student's success in the course (achievement of a "C" or higher). Overall, it was found that the three statistically significant factors were 1) the course the student was enrolled in, 2) whether the student had prior computer science experience, and 3) whether the student represented a historically minoritized population. Using a Wald's test, it was determined that students enrolled in the standard pace course offered in the computer science department were between 0.051 and 0.586 times less likely to fail than those enrolled in the equivalently paced course offered by the engineering department. In terms of prior computer science experience, students that entered any of the courses without prior experience were between 1.04 and 10.10 times more likely to fail than students that had any type of experience. Finally, students representing historically minoritized populations were between 1.27 and 6.29 times more likely to fail a 100-level computer science course compared to their white counterparts. These two latter results are especially concerning since 45% of all participants (49% from historically minoritized populations) reported not having prior experience despite nearly 70% of public high school students in the state of Michigan having access to a foundational computer science course. If gaining even some type of computer science experience during a student's K-12 career

is a leading factor in whether a student is successful in the subject at a collegiate level, then more work needs to be done to prepare students. Educators could do so by providing more access to experience with computer science as well as coaching students to increase their digital literacy as they consider pursuing degrees in engineering or computer science.

Introduction

Student success in first-year engineering programs has been a significant focus for over 20 years as universities look to improve retention rates and graduate highly qualified individuals ready to meet industry needs[1]. One required course that most if not all engineering students must complete within their first year is introduction to computer science where students develop fundamental skills in building algorithms to solve problems. Although advancements in instructional materials (interactive online textbooks, auto-graded labs, project-based learning, etc.) have been shown to help with student engagement and success, pass rates for these types of classes are still of concern [2,3]. Engineering students enrolled in a first-year programming course at a regional university in the American Midwest are no exception to this problem where pass rates have averaged below 70% over the past four years despite enhancements in course materials and design[4]. In a more recent study at this same institute, student preparation in computer science at the K-12 level was explored to determine if there was a correlation with student success (defined as earning a passing grade of ‘C’ or higher) in a first year applied programming course required for engineering majors[5]. The study focused on Michigan high school graduates where up to 70% of public high school students were reported to have access to a foundational computer science course[6]. The results demonstrated that nearly 60% of students reported not having any prior experience with computer science and withdrew from the course at nearly double the rate of students with AP experience. Although this study offered some insights into why a student may not be successful in a first-year programming course, it did not explore other factors that might limit a student’s preparation such as highest math level achieved, total enrolled credits or demographic information such as region of residence, gender, and race. In addition, the study did not include students enrolled in a similar first year programming course offered for both computer science majors and non-majors in the computer science department. Finally, with the introduction of a new “stretch” version of the course that splits the content of the standard course offered by the engineering department into two semesters, student success rates have not been well established. The goal of this study was to investigate these factors to determine if and to what extent they play a role in student success in a first-year computer science course.

The state of Michigan, like many states, has been working towards increasing access to computer science education at the K-12 level. In a 2024 annual report from the Code.org Advocacy Coalition, Michigan ranked 34 out of 50 states in terms of access[7]. Within the Midwest region, Michigan falls behind Ohio, Illinois and Indiana in terms of number of computer science related policies and the presence of a state plan. Given that the state of Michigan has an estimated K-12 student population of 1.2 million and a long history of research and development, manufacturing and technology, it is surprising that access to computer science education is not more readily available for elementary and secondary aged students[8,9]. To combat this deficit, a recent piece of state legislature, House Bill 5649, was passed in 2025 that will require all public secondary schools (grades 9 – 12) to offer a foundational year-long computer science class starting in the 2027-2028 school year[10]. In the meantime, state-wide organizations are continuing to promote access through teacher training and long-term program development[11]. The current study serves to determine if access and overall success is improving in the state of Michigan given these efforts.

Underrepresentation of female and historically minoritized ethnic groups in computer science and engineering is a known issue. Numerous studies have been conducted to understand the causes and to develop strategies to close the gap[12-16]. In a study by Taylor and Mounfield, it was found that female college students enrolled in an introductory computer science course performed as well or higher than their male counterparts especially when they had access to computer science prior to college[15]. In a more recent study, it was observed that although female students performed at the same level as males, they perceived that they were less likely to succeed and needed to devote more time and effort into the course[16]. In this same study, it was found that black students performed lower than white students and often reported lower levels of empowerment and interest than other historically minoritized populations such as Asian and Hispanic. Given the observations of previous studies, one of the goals of the current study was to determine if student success for student populations such as those mentioned above is comparable in the state of Michigan especially given efforts to increase access at the K-12 level.

To understand the effects of the continually evolving landscape of computer science education on student success in a first-year computer science class, a follow-up study was launched. Unlike the first study that focused on three categories of computer science experience in a first-year applied programming course for engineers (none, other and Advanced Placement), this study expanded multi-fold. First, it included students that were enrolled in a comparable course offered by the computer science department as well as students that were enrolled in a "stretch" version of the course offered by the engineering department. In addition, the types of computer science experience (AP, trimester, student club, etc.) for students to select were expanded along with the opportunity to include demographic information. Using this information, a multi-variate linear regression model was developed along with Wald's Odds testing for variables that were found to be significant.

Experimental Method

Institution and Courses

The data for this study was collected during the Fall 2024 semester from a mid-size accredited university in the state of Michigan serving over 19,000 undergraduate students. Three different 100-level courses were selected for the study, two offered in the school of engineering (EGR Stretch and EGR 1XX) and one offered in the school of computing (CIS 1XX). A comparison of the topics and layout for the three courses are represented in Table 1 below. It should also be noted that students enrolled in the courses offered by the school of engineering had declared engineering as a major while the course offered by the school of computing included both computer science and non-computer science majors. Also noteworthy is the "stretch" version of the Applied Programming for Engineers course, a new offering that reduced the required math level as well as content covered compared to the other two course offerings.

Table 1: Description of 100-Level computer science courses involved with the study (Note: Y – Yes and N – No)

	Applied Programming for Engineers – Stretch EGR Stretch	Applied Programming for Engineers EGR 1XX	Computer Science 1 CIS 1XX
Math Pre-requisite	College Algebra	Pre-Calculus	College Algebra
Credits	2	2	4
Language	C	C	Python
Lecture	Y	Y	Y
Lab	Y	Y	Y
Common curriculum/syllabus	Y	Y	Y
Topics			
Input/Output	Y	Y	Y
Variables/Datatypes	Y	Y	Y
Functions/Methods	Y	Y	Y
Logic/Conditionals	Y	Y	Y
Iteration/Loops	Y	Y	Y
Arrays/Lists	N	Y	Y
Files	N	Y	Y
Classes/Structs	N	N	Y
Macros	N	Y	N
Pointers	N	Y	N

Participants and Test Instruments

All students enrolled in one of the three courses listed in Table 1 above were invited to participate by completing a survey about their prior computer science experience as well as year and region of high school graduation, math enrollment, total number of enrolled credits, gender and race. As in the previous study, only Michigan high school graduates and students that had enrolled in one of the three courses for the first time were included. It should be noted that this study received approval from the university's institutional review board (IRB# 22-124-H), all questions were optional, information was kept confidential, and students were allowed to withdraw from the study at any point. Upon completion of the semester, the final course grade was recorded for each student.

Assumptions and Limitations

The primary research method employed was survey research. It was assumed that all student responses were accurate. In addition, each of the three courses were taught by 4 or more different instructors using a common curriculum and grading scale; thus, an individual instructor's style was assumed to be a minimal effect. In terms of final grades, any student that withdrew from the course before the end of the semester was assumed to not pass and received a grade of 'F'. For limitations, it must be noted that although statistical means were used to test for significance, the observations and conclusions may not represent the bulk population. Another consideration is that although this study focused on the effects of prior computer science experience on student success, there are multiple reasons that students may not pass a course. Outside commitments such as a job, extracurricular activity, family responsibility as well as both physical and mental health may all affect a student's ability to succeed and must be noted as a possible limitation.

Results

Survey results

The summarized results of the student survey are presented below. The response rate from the entire population was 232 out of 511 enrolled students (45%). Of the responders, 187 qualified for the study as they were both Michigan high school graduates and enrolled in one of the courses for the first time. Table 2 includes a breakdown of the participants. Although not planned, the number of participants for each course was nearly the same, between 60 and 64. It was also observed that greater than 80% of the students that were enrolled in the stretch course were 2024 high school graduates, over double the percentage of graduates from the other two courses. For prior computer science experience, only 41% of students enrolled in the stretch course reported having any prior experience while 70% of those enrolled in the course offered by the computer science department had some level of prior experience. Finally, although the population of white participants was similar for all classes (between 70 and 77%), the percentage of students that reported male as a gender was over 10% less for the regular paced course offered by the engineering department compared to the other two courses.

Table 2: Summary of Self-Reported Participant Data

	EGR Stretch	EGR 1XX	CIS 1XX
Total Participants	63	60	64
2024 graduates (%)	83	38	30
prior experience - none (%)	59	47	30
Race - white (%)	70	77	75
Gender - male (%)	83	68	80

Note: Four students chose not to respond to the question about race while two students chose not to respond to the question about gender.

The type of experiences and languages students reported having exposure to are represented in Figures 1 and 2 below. As indicated in both Table 1 and Figure 1, students enrolled in the CIS

1XX course reported the most prior experience while students in the EGR stretch course reported the least prior experience. It was observed that over 20% of students participated in a semester or trimester long course, three times as many students completed AP Computer Science Principles (AP CSP) compared to the traditional AP CSA course, and 10% of students reported being self-taught. In terms of programming languages, Python was the most common with nearly 30% of students reporting its use. Other commonly selected languages were HTML, Scratch/Block-based, and Java/JavaScript. The least commonly reported were C, C#, and C++.

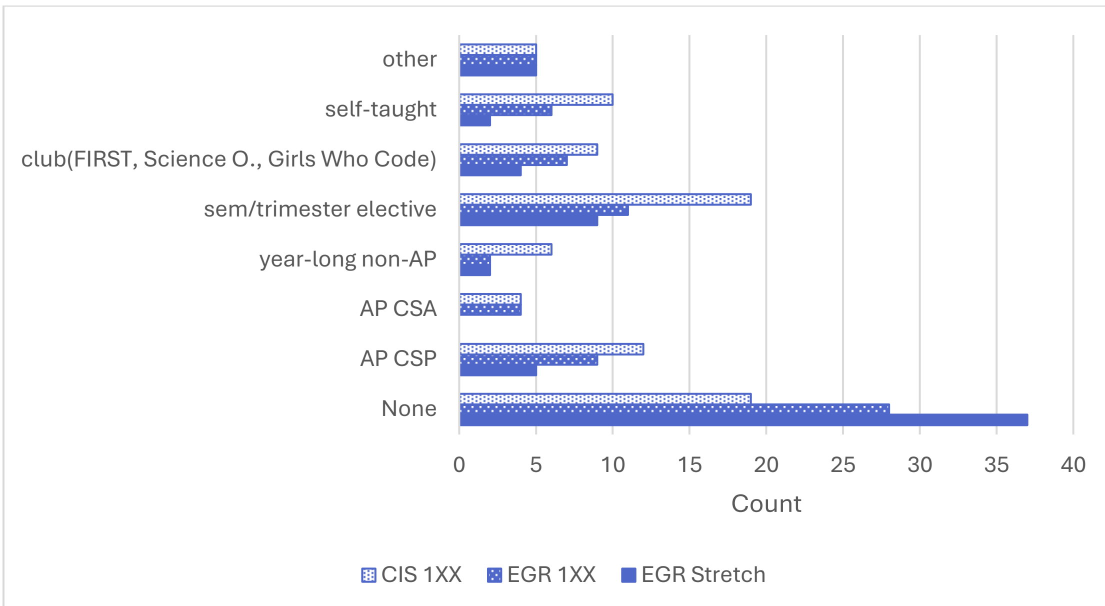

Figure 1: Student computer science experience (count) prior to college

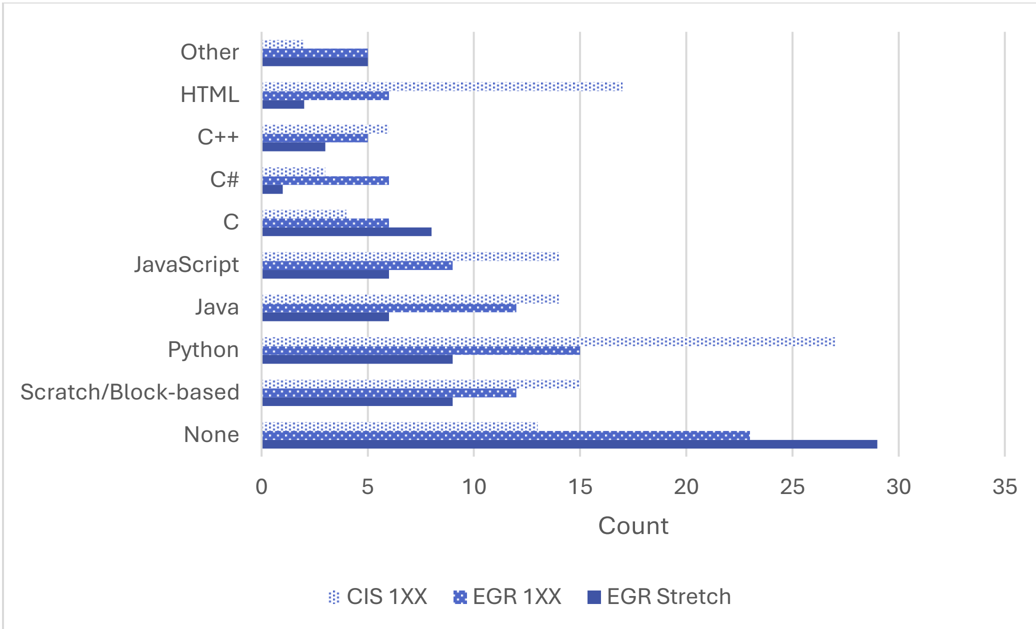

Figure 2: Programming languages used prior to college (count)

Additional variables explored were region of high school graduation, number of enrolled credits, and math enrollment. Using the regions as defined by the Michigan Association of Superintendents represented in Figure 3[17], the top two regions were Region 3 (79 students) and Region 9 (27) with other regions having 13 or less students. It should also be noted that 20 students did not respond to this question. In terms of enrolled credits, 86% reported 12-15 credits with the remainder being 16 or more credits. Finally, 125 students (67%) reported being enrolled in a 200-level math class such as Calculus 1 or higher.

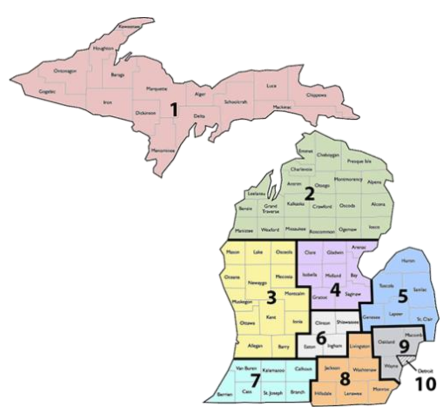

Figure 3: Michigan Association of Superintendents Regional Map[17]

Student Performance

The student success rate for each course is displayed in Figure 4 below. Passing was defined as 73% ('C') or higher. In total, less than 10% of students withdrew from one of the three courses before the end of the semester, 5 from EGR Stretch, 8 from EGR 1XX and 2 from CIS 1XX. CIS 1XX had the highest rate of passing at 89% while EGR 1XX had the lowest rate at 68%.

Figure 4: Student final success rate for each course

Statistical Analysis

To better understand the factors that may influence a student's rate of success in a first-year programming course, a multi-variate linear regression model was created. This type of model was chosen as it allows for the testing of a hypothesis dealing with the relationship of a categorical outcome (eg, pass or not pass) with one or more categorical variables (designated as the "effects")[18]. For this type of analysis, it was first required to assign each "effect" with a degree of freedom, 1 or 2. All effects were based on the survey questions answered by the participants. A degree of freedom of 1 meant there were only two conditions. For example, a student was either from Region 3 (the most common) or not or a student reported having experience with programming languages or none. Race was assigned a degree of 1 (white or not white) since the students representing historically minoritized groups (Hispanic, Black, Asian, Middle Eastern, American Indian) made up 26% of the total population but were individually low enough to be identifiable. A degree of 2 was associated with one of three conditions. Two effects, *Course* and *Prior Experience*, met this category. The *Course* effect meant the student was either in EGR Stretch, EGR 1XX or CIS 1XX while the *Prior Experience* effect meant students had either no prior experience, some, or Advanced Placement (AP). In addition, it should be noted students that reported AP experience were placed in this category even if they had some other type of experience. One variable, total enrolled credits, was not included as an effect due to nearly 90% of students reporting 12-15 credits. Once effects were assigned, the Wald Chi-Squared value and probability (Pr) were determined. The results are presented in

Table 3 below. Based on the analysis, three effects were identified as statistically significant (Pr value less than 0.05): *Course*, *Race*, and *Prior Experience*.

Table 3: Multi-Variate analysis of effects based on student survey responses

Effect	Degrees of Freedom	Wald Chi-Square	Pr > ChiSq
Geographic Region: Region 3 vs. not Region 3	1	0.1432	0.7051
Course – EGR Stretch, EGR 1XX, or CIS1XX	2	7.9927	0.0184
Race – White: No vs Yes	1	6.5053	0.0108
HS Graduation Year – 2024: No vs. Yes	1	0.1387	0.7095
Prior Experience – None, Other, or AP	2	6.0629	0.0482
Programming Languages – None vs. Some	1	0.9911	0.3195
Gender – Not Male vs. Male	1	0.3302	0.5655
Math Course - 100 level vs. 200+	1	0.8053	0.3695

To extend the multi-variate analysis, a Wald's Odds test was run to check for significance. The results are represented in Table 4 and Figure 4 below. An effect is deemed significant if the confidence interval does not contain 1. Based on the test, three effects were found to be significant: **2:** Course - CIS 1XX vs. EGR 1XX, **4:** White - No vs. Yes, and **7:** Prior Experience - None vs. Other. Specifically, the odds of a student who completed the CIS 1XX course failing were 0.051 to 0.586 times lower than that of a student who completed the EGR 1XX course. In terms of race, the odds of a student from a historically minoritized population (non-white) failing one of the three courses were 1.272 to 6.287 higher than a student that identified as white. Finally, the odds of a student with no prior experience failing one of the three courses were between 1.039 and 10.104 times higher than a student with other (non-AP) experience.

Table 4: Odds Ratio Estimates and Wald's Confidence Intervals

Effect	Estimate	95% Confidence Limits	
1. Geographic Region: Other vs #3	1.169	0.521	2.622
2. Course: CIS1XX vs EGR1XX	0.174	0.051	0.586
3. Course: EGR Stretch vs EGR1XX	0.349	0.109	1.119
4. Race - White: No vs Yes	2.828	1.272	6.287
5. HS Graduation Year_2024: No vs Yes	1.175	0.502	2.750
6. Prior Experience: AP vs Other	0.527	0.116	2.386
7. Prior Experience: None vs Other	3.240	1.039	10.104
8. Programming Languages: None vs Some	0.583	0.202	1.686
9. Gender: Not Male vs Male	0.755	0.289	1.971
10. Math level: 100 vs. 200+	1.634	0.559	4.771

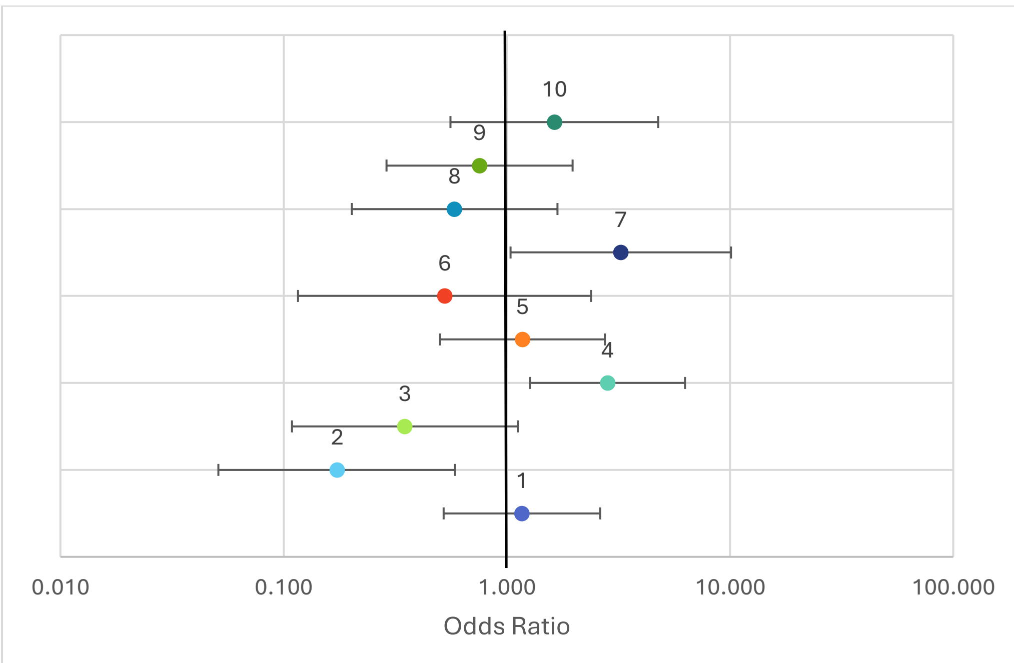

Figure 4: Odds Ratio testing results based on numbered effects represented in Table 4

Discussion:

The goal of this study was to develop a better understanding of factors that influence a student's rate of success in a first-year programming class given the strides that have been made towards increasing access at the pre-collegiate level. Based on the results of this case study, three factors were identified as possible indicators for a student's success; 1) which course the student was enrolled in, 2) whether the student was from a historically minoritized population or not, and 3) whether the student had any prior type of computer science experience. In addition, surveying the students allowed a deeper look into the types of experiences and languages they had worked with. Like the previous study, less than 20% of the participants completed an AP Computer Science course [5]. Also, the most reported type of experience was through either a trimester or semester length course. As the state of Michigan moves towards requiring a yearlong foundational computer science course at the secondary level, it should be considered if a trimester or semester length course could meet the same needs. It was also interesting to see students reporting “self-taught” which was not seen in the past study. In terms of languages, although there were over 10 different languages reported, the largest set was Python particularly for students enrolled in CIS 1XX. This may have contributed to the higher pass rate (89%) compared to the other two courses considering Python was the language used during the course. Changing the language from C to Python may be something for the engineering department to consider to better meet students where they are. Also, the EGR stretch course tended to be more popular for the most recent high school graduates, possibly allowing students to adjust to the pace of college while tackling the material at a slower rate. This is a factor to continue to monitor.

As suggested by statistical analysis and past studies, only one demographic factor was significant, race. Students that identified as white were more likely to pass one of the three courses compared to students representing a historically minoritized population. From the survey, it was found that 49% of students from this population also reported receiving no prior computer science training. This should be considered as an area of focus and opportunity by those involved in implementing Michigan State House Bill 5649. In addition, it should be noted that math level was not found to be a significant factor. This differs from past studies that found students that are “Calc Ready” or have already completed a Calculus course in high school are more likely to pass a first-year computer science course [19]. The current study showed higher pass rates for the CIS 1XX and EGR Stretch course, both of which do not require students to be “Calc Ready”. This may be a new trend as access to computer science education continues to increase. Both first-year course builders as well as high school counselors working with students considering a degree in engineering or computer science should consider this potential shift.

Although this study revealed a variety of factors that may influence the success rate of today’s students enrolled in a first-year computer science course, there are some limitations. First, multivariate linear regression can test statistical significance, but the Wald’s Odds test only provides a range (eg, a student with no prior experience may fail at a rate between 1.039 and 10.104 times higher than a student with other (non-AP) experience); it cannot provide an exact value. A larger sample size may help to narrow this range giving a more representative rate of passing. In addition, there were 20 students that did not report the region of their high school graduation. It was therefore assumed that they were not from Region #3, one of the effects used in the analysis. This may have affected the results. In terms of race, students that reported both white and a historically minoritized group were placed in the latter group. Despite these limitations, allowing students to self-report may have allowed for a more representative look at their background entering one of the three classes. These results can also be used by secondary and post-secondary educators involved with curriculum planning for first year engineering and computer science students.

Conclusion:

Computer science education in pre-collegiate settings continues to evolve to encourage as well as prepare students for careers that rely on understanding the fundamentals of computational thinking. This preparation is especially important for students pursuing a degree in engineering and computer science. While this movement is occurring at the national level, many states including the state of Michigan, are working towards increasing access to computer science education through new policies and programs. The goal of this study was to capture student preparation as they enter a first-year programming course by exploring the effect of multiple factors such as prior computer science experience, math level, and demographics on student success. By using multi-variate linear regression with this data, it was found that a student receiving any type of computer science experience has an advantage over students that enter a collegiate level course without prior experience. This is especially compelling since nearly half of the participants representing historically minoritized populations reported not having prior experience despite nearly 70% of public high school students in the state of Michigan having access to a foundational computer science course. This presents an opportunity for those involved with implementing the state-wide requirement for a yearlong foundational computer science course in the 2027-2028 academic year. Based on the results of the current study, it is recommended to continue monitoring the preparation and success of students enrolled in first-year computer science courses to determine if increases in access and participation lead to an upward trend in student pass rates.

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