Study Major, Gender, and Confidence Gap: Effects on Experience, Performance, and Self-Efficacy in Introductory Programming

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*Abstract—Full research paper—*The term Confidence Gap refers to the phenomenon of men being more confident in their ability to succeed in their studies and elsewhere. It is an acknowledged phenomenon both in Computer Science as well as STEM subjects at large, likely influencing students' career path choices and selection of study major. In this work, we analyze data from multiple introductory programming courses. We do this by looking at the interaction of (1) students' performance measured in terms of completed assignments, (2) self-reported confidence in the ability to succeed in the programming course, (3) major, and (4) gender. Aligned with prior research, we observe the existence of the Confidence Gap. At the same time, men and women who chose Computer Science as their major are more confident in their ability to succeed in their first programming course than their counterparts in other subjects.

*Index Terms—*introductory programming, CS1, gender, persistence, self-efficacy, confidence, interest, performance

I. Introduction

STEM fields have generally suffered from high drop-out rates and students either switching their major for a non-STEM field or leaving tertiary education altogether before finishing a degree [1]. Such phenomenon is amplified with women, who are already under-represented in STEM fields – recent studies have shown that STEM subjects, in general, suffer from lower retention rate for women than men [2], [3], computer science being no exception to this [4]–[6]. Even though the number of women participating in programming courses and majoring in computer science has been growing over the years, the field is still predominantly male [4], [5], [7].

One of the possible reasons for the lower retention rate is the existence of a confidence gap, a significant difference in confidence between men and women [8]. Confidence gap exists despite performance [9], and even if there is no difference in exam performance, women are more likely to e.g., underpredict their final score than men. While gender-related differences in self-efficacy have been studied [4], [8], [10]–[14], except for [15], little work has been done comparing the effects of the confidence gap when taking the students' major into account.

As confidence and feeling of belonging are factors that affect a person's choice of career [2], a better understanding of the relationship between these two factors could give us knowledge and tools to help alleviate the issues of confidence gap. In the present work, we examine student-reported confidence in succeeding in an introductory programming course between gender and majors, comparing how self-efficacy varies between men and women majoring in computer science, STEM fields, or fields outside of STEM. We investigate whether students who have chosen computer science as their major are more confident in their abilities to learn to program, and if there are differences when it comes to STEM and non-STEM majors. We also study these groups' performances, taking into account that computer science majors generally have more previous programming experience than students from other fields.

This article is structured as follows. In the next section, we explore some relevant background, focusing on previous studies on the confidence gap, and women in CS and other STEM fields. In Section III, context, methodology and data are described in detail. Section IV presents the results, and Section V discusses the implications of this study, as well as the limitations. We conclude with the main findings and future work in Section VI.

II. Under-representation of Women in CS and Confidence Gap

The under-representation of women in CS is a widely reported phenomenon in the literature. Fewer women are taking CS at the college level [16], [17], which is also reflected by the lower number of female authors on CS conference publications, and the lower number of female role models. There is recent evidence, however, that the number may be rising [18].

One of the factors directly affecting the under-representation of women in CS is the confidence gap, that is, women reporting lower confidence than men [15], [19]. In general, men self-report higher levels of confidence when it comes to their performance on CS courses compared to women [20]–[22], even if this confidence does not relate to the actual performance on CS courses. Prior work has found no difference between the genders in terms of course grades [6],

[22] or in terms of performance in programming exercises and exams [21]. Some studies have even reported that women in CS had somewhat higher point averages [20].

The confidence gap is not just a phenomenon in CS. Studies that report differences in confidence range from primary education to higher education levels. For example, Ross et al. [8] found that girls had lower self-efficacy in mathematics in primary education, although the actual difference in performance between girls and boys was negligible. Similarly, this lower confidence is present at the other end of the educational spectrum; women in academia are less confident than men about reaching a professoriate position before retirement [23]. As confidence influences choices, including the selection of major [24], it is not surprising that researchers are seeking to understand the phenomenon.

The persistence of women in STEM fields is not only limited to academic environments. Cech et al. [25] introduce the concept of professional role confidence, that is, individuals' confidence in their ability to successfully fulfill their roles, competencies, and identity features in a profession. Cech et al. (ibid.) argue that the lack of self-efficacy reduces women's likelihood of remaining in engineering majors and careers, even after entering working life. If women develop less confidence in their professional abilities early in their careers, they are more likely to switch fields.

Similarly, Lishiski et al. [6] note that men and women modify their self-efficacy beliefs differently in response to feedback. Women tend to revise their self-efficacy belief earlier in the course, which would suggest that early feeling of failure in computer science courses could disengage women from programming and computer science studies easier. Kinnunen & Simon [26] showed that many programming assignments are characterized by their tendency to catch novice students off guard with their difficulty. Thus, a batch of challenging programming exercises at the beginning of the course could lead to more female students dropping out, as their already lower self-efficacy is reduced further.

For students completing a minor in CS or just taking a single course, the course content's relevance is a factor in dropping out. Kinnunen & Malmi [27] investigated the reasons for minor students dropping out of a CS1 course and found that relevance to other studies was often cited as a reason for not completing the course.

III. METHODOLOGY

A. Context

The context of this study is a public research-first University in Northern Europe. Students entering the university select their major before enrollment during the application process. This means that once a student starts as a freshman, they have their major already selected. Minor studies can be, however, selected freely. Some students also end up changing their majors during their studies.

The study is situated in a 7-week introductory programming course (CS1). The course content is typical to many introductory programming courses around the world, teaching students about standard input, standard output, variables, conditional statements, loops, functions, objects, and object-oriented programming. The programming language in the course is Java, which is also the main programming language for subsequent CS courses.

The course uses an online textbook with integrated programming assignments and activities, and synchronous and asynchronous discussion channels for peer support. The course is offered multiple times each year. During the fall iterations, the course has lectures, while there are no lectures during the spring or summer iterations. All course iterations have walk-in labs where students can come and work on the assignments and ask for additional support. The course assignments are automatically assessed, and the course uses a many-assignments approach, where students complete tens of programming assignments each week.

To pass the course, the students must take an end-of-course exam and complete a set minimum amount of programming assignments. The grading is based on the assignments and the end-of-course exam, where both amount for approximately the same amount of course points. To reach the best grade, the student needs to receive over 90% of the overall course points, while the lowest passing grade requires at least 50% of the overall course points. The student must also receive at least half of the points from the exam to pass the course.

B. Data and Research Questions

We collected data from five iterations of the course, offered between 2017–2019. At the beginning of each course iteration, students were given a voluntary survey which asked for research consent, background information including their gender, year of birth, previous programming experience (in terms of hours programmed), and on whether the student expects to do well in the course.

From the data, we removed students who (1) did not provide research consent, (2) had no major (non-affiliated students), (3) had more than one major, and (4) did not complete any assignments in the course. Furthermore, as our focus is on students who self-identified as female or male, students who chose not to disclose their gender or selected another option were omitted (3% of participants). The final data used in this analysis consists of 640 responses (43% of affiliated students who signed up to the course through the University system).

Analyzing the survey data and students' performance in the course, we ask the following research questions:

RQ1 What are the previous programming experience differences between majors and genders?

RQ2 What are the performance differences between majors and genders?

RQ3 What are the differences in self-efficacy between the majors and genders?

C. Approach

In this work, we define performance as the total completed course assignments. Students' major is divided into three categories: CS ($n = 180$), STEM ($n = 193$), and Other

($n = 267$). CS contains only those students with computer science as a major, the STEM category includes chemistry, physics, and mathematics, and the Other category includes majors such as agriculture, biology, linguistics, geography, medicine, and philology. In the studied context, engineering is not offered as a major.

During the analysis, as the total completed course assignments and self-efficacy scores are not normally distributed, we use non-parametric tests of statistical significance (Mann-Whitney U test unless otherwise noted). The $r_{equivalent}$ from [28] is used as effect size estimate for non-parametric tests in our analysis. Following[1], we interpret $0.1 < r < 0.3$ as small effect size, $0.3 \leq r < 0.5$ as medium effect size, and $r \geq 0.5$ as large effect size.

In the analysis, we use Bonferroni correction for multiple comparisons. All reported p-values are corrected values. Values where $p < 0.0000001$ are reported as $p < 0.00$, and larger values where p is rounded to 0.00 are reported as $p = 0.00$. We report values where $p < 0.05$ after correction as statistically significant. Values in tables are rounded to two decimal places.

IV. RESULTS

A. Previous Experience

Descriptive statistics on students' previous experience in terms of total hours programmed is shown in Table I. Since there is a huge variation in students' previous experience, the means are skewed towards high amounts of experience, but the medians show that students were mostly beginners.

TABLE I
DESCRIPTIVE STATISTICS OF PREVIOUS PROGRAMMING EXPERIENCE (REPORTED IN NUMBER OF HOURS) BY GROUP AND GENDER.

	CS		STEM		Other	
	M (137)	F (43)	M (120)	F (73)	M (122)	F (145)
M	681.57	161.67	475.10	1216.36	423.50	977.09
Median	50.0	22.5	13.5	10.0	10.0	1.5
SD	3986.75	769.2	4093.4	7140.6	4051.5	6384.6

When comparing the difference in previous experience between majors, summarized in Table II, we observe a statistically significant difference between CS and STEM ($r = 0.3, p < 0.00, W = 21332$) and CS and Other ($r = 0.38, p = 0.00, W = 3117$) and medium effect sizes. The is no statistically significant difference between STEM and Other courses ($p = 0.31, W = 27038$).

TABLE II
EFFECT SIZE (R) DIFFERENCES OF MEANS IN EXPERIENCE BETWEEN MAJORS.

Majors	Effect size
CS - STEM	0.30 (p = 0.00)
CS - Other	0.38 (p = 0.00)
STEM - Other	ns (p = 0.31)

As summarized in Table III, there are statistically significant differences in previous programming experience between men and women in Computer Science ($r = 0.29, p = 0.00, W = 3716.5$) with a small to medium effect size. No statistically significant differences in the previous programming experience between men and women in STEM or Other subjects were observed.

TABLE III
DIFFERENCE IN PREVIOUS PROGRAMMING EXPERIENCE WITHIN MAJOR BY GENDER.

	CS	STEM	Other
Experience (M - W)	r = 0.29 p = 0.00	r = ns p = 1.00	r = ns p = 1.00

When studying the differences in previous programming experience between men and women across the majors, shown in Table IV, we observe that there is a statistically significant difference in previous programming experience between men in CS and men in STEM and Other ($r = 0.36, p < 0.00, W = 10314$ and $r = 0.44, p < 0.00, W = 11114$ respectively). No statistically significant difference in terms of previous programming experience between men in STEM and Other is observed.

When studying the difference in previous programming experience between women in CS and women in STEM and Other, also in Table IV, no statistically significant differences are observed between any of the groups.

TABLE IV
EFFECT SIZE (R) DIFFERENCES BETWEEN MAJORS IN PREVIOUS PROGRAMMING EXPERIENCE BY GENDER.

Majors	Effect size (men)	Effect size (women)
CS - STEM	0.36 (p <0.00)	ns (p = 1.00)
CS - Other	0.44 (p <0.00)	ns (p = 1.00)
STEM - Other	ns (p = 1.00)	ns (p = 1.00)

B. Performance

Course performance descriptive statistics in terms of completed assignments divided by major and gender are shown in Table V. The performance is given on a scale from 0 to 100, where 100 means that the student completed all of the assignments in the course, while 0 means that the student did not complete any of the assignments. From Table V, we observe that the median performance is higher than the average performance, indicating a skew in the data. This is especially visible in CS, where the median performance for both men and women is over 98, while the average is around 88, with approximately 1.4 point difference between men and women.

When comparing the difference in performance between majors, summarized in Table VI, we observe a statistically significant difference between CS and STEM ($r = 0.34, p = 0.00, W = 24178$) and CS and Other ($r = 0.34, p = 0.00, W = 33461$). No statistically significant difference is observed between STEM and Other ($p = 1.00, W = 25792$).

When comparing the difference in performance between men and women within each major, summarized in Table VII,

	CS		STEM		Other	
	M (137)	F (43)	M (120)	F (73)	M (122)	F (145)
M	88.76	87.30	81.35	73.26	83.37	74.55
Median	99.49	98.31	93.57	86.14	94.42	86.73
SD	25.88	23.77	25.67	28.85	23.51	28.07

Majors	Effect size
CS - STEM	0.34 (p = 0.00)
CS - Other	0.34 (p = 0.00)
STEM - Other	ns (p = 1.00)

we observe no statistically significant difference in CS ($p = 1.00, W = 3489.5$), STEM ($p = 1.00, W = 5150$) or Other ($p = 0.11, W = 10709$).

	CS	STEM	Other
Performance (M - W)	p = 1.00	p = 1.00	p = 0.11
	r = ns	r = ns	r = ns

We then compared the differences in performance between majors by gender. There is a statistically significant difference in performance of men in CS and men in STEM as well as men in Other ($r = 0.34, p = 0.00, W = 11404$ and $r = 0.30, p = 0.00, W = 11175$ respectively). No statistically significant difference is observed between men in STEM and men in Other ($p = 1, W = 7010.5$). For women, there is a statistically significant difference in performance of women in CS and women in STEM and Other ($r = 0.31, p = 0.03, W = 2159.5$ and $r = 0.27, p = 0.01, W = 4291.5$ respectively), while no statistically significant difference between the performance of women in STEM and women in Other is observed ($p = 1.00, W = 5205.5$).

Majors	Effect size (men)	Effect size (women)
CS - STEM	0.34 (p = 0.00)	0.31 (p = 0.03)
CS - Other	0.30 (p = 0.00)	0.27 (p = 0.01)
STEM - Other	ns (p = 1.00)	ns (p = 1.00)

C. Self-Efficacy

Self-efficacy was measured using the statement *I believe I will do well on this course*, for which the students gave a response using a 7-point Likert-scale ranging from *Strongly Disagree* to *Strongly Agree*. The responses to the questionnaire are summarized in Figure 1 – as shown in the figure, there is a visible difference in responses in all groups. Men in CS

were the only group that had no negative responses to the questionnaire.

When comparing the difference in self-efficacy between majors, summarized in Table IX, we observe a statistically significant difference between CS and STEM ($r = 0.36, p < 0.00, W = 24461$) and CS and Other ($r = 0.41, p < 0.00, W = 35411$). No statistically significant difference is observed between STEM and Other ($p = 1.00, W = 28584$).

Majors	Effect size
CS - STEM	0.36 (p = 0.00)
CS - Other	0.41 (p = 0.00)
STEM - Other	ns (p = 1.00)

When comparing the difference in self-efficacy between men and women in each major, summarized in Table X, we observe a statistically significant difference in all majors: ($r = 0.26, p = 0.00, W = 3944$) for CS, ($r = 0.30, p = 0.03, W = 5913.5$) for STEM, and ($r = 0.23, p = 0.05, W = 11195$) for Other.

	CS	STEM	Other
Self-efficacy (M - W)	p = 0.02	p = 0.00	p = 0.05
	r = 0.26	r = 0.03	r = 0.23

We then compared the differences in self-efficacy between majors by gender, summarized in Table XI. There is a statistically significant difference in self-efficacy of men in CS and men in STEM as well as men in Other ($r = 0.36, p = 0.00, W = 11546$ and $r = 0.40, p = 0.00, W = 12062$ respectively). No statistically significant difference is observed between men in STEM and men in Other ($p = 1.00, W = 7921.5$). At the same time, for women, there is no statistically significant difference between the groups.

Majors	Effect size (men)	Effect size (women)
CS - STEM	0.36 (p = 0.00)	ns (p = 0.27)
CS - Other	0.40 (p = 0.00)	ns (p = 0.08)
STEM - Other	ns (p = 1.00)	ns (p = 1.00)

Finally, we compared the self-efficacy of men and women across the groups. There is no significant difference in self-efficacy between women in CS and men in STEM ($W = 2593.5, p = 1.00$). Same for Other ($W = 2795.5, p = 1.00$).

V. DISCUSSION

A. Differences in Programming Experience

Studies that have looked into previous programming experience have, in general, found that women in introductory
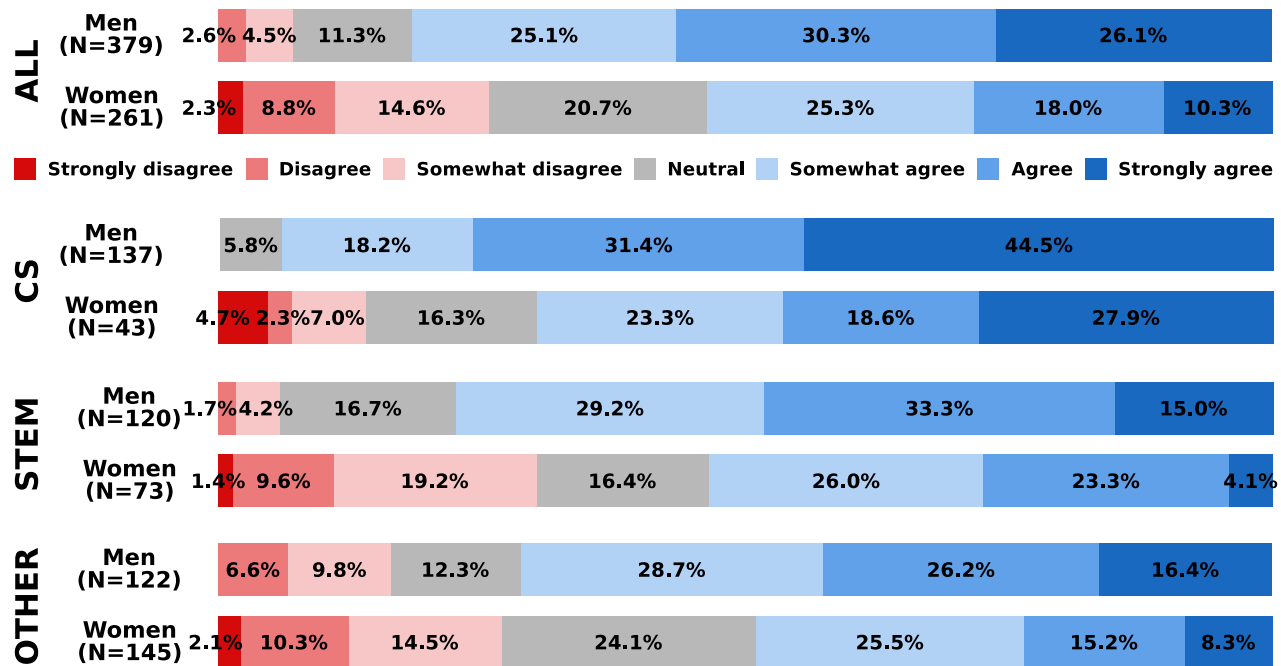
Fig. 1. Self-efficacy for different student populations: All, CS, STEM, and Other. The STEM group does not include CS students and Other group does not include STEM or CS students.

programming courses are less likely to have previous programming experience than men [17], [29]. Several factors contribute to this phenomenon [12], [15], including stereotypes, parental influence, video games, interest towards computers and electronics, and popular culture, including the infamous "math class is tough"-Barbie doll. Insufficient early experience and prevalent (masculine) culture also contribute to the lower percentage of women choosing CS as a major [30].

In the studied context, typically, 20-25% of starting CS majors self-identify as women, which is similar to the US [31]. When looking at the differences in previous programming experience by gender and majors, summarized in Table III, we observe that men majoring in computer science have more previous programming experience than any other group, including women majoring in computer science and students from other fields, regardless of gender or major. Women majoring in computer science do not have significantly more previous programming experience than women in other fields. Moreover, there is no statistically significant difference in previous programming experience between STEM and non-STEM majors, regardless of gender.

B. Differences in Performance

In general, both major and gender have been used in studies that seek to explain students' performance [32]. Previous studies that have looked into gender and performance in introductory programming courses have, overall, reported mixed results. For example, neither Werth [22] nor Ventura [21] found a statistically significant correlation between introductory programming course outcomes and gender. While in our case, men had marginally more points than women but the

difference was not statistically significant, Byrne and Lyons had a similar but opposite observation [20]: in their study, women in introductory programming had marginally more points than men, although the difference was not significant.

When studying students' performance, we observed no differences in performance between men and women in CS, while men and women in CS outperform students in other majors. While the data indicates that, in other subjects, men complete more assignments than women, this difference was not statistically significant. These results are interesting in light of our analysis of previous programming experience, where we observed that men in CS have more previous programming experience than others, including women in CS. Should previous programming or computing experience contribute to course performance (e.g., [33], [34]), women in CS should have performed worse than men in CS – this was not the case. Instead, women in CS performed equally to men in CS and outperformed women in other subjects.

Our results could, at least to some extent, be explained by students' motivations. If a student chooses CS as their major, they are likely to direct their effort to it. On the other hand, choosing minor subjects can be done at any time, and some of the students from STEM and Other majors may still be sampling their options.

C. Differences in Self-Efficacy

When looking at the responses on the statement *I believe I will do well on this course*, summarized in Figure 1, we observe the following. Of those who have self-identified as men, 27 out of 379 have disagreed with the statement at least to some extent, while 67 out of 261 women disagreed

with the statement at least to some extent. This difference (7.1% vs 25.7%) is statistically significant, and is in line with previous studies [15], [19]. There were differences in confidence between men and women within each major.

At the same time, our results suggest that there are no statistically significant differences in the confidence of women who have signed up to study computer science and men who have signed up to study other subjects than computer science, contradicting results from Beyer et al. [15]. Similar results to ours have previously been identified in mathematics [35], but to our knowledge, not in CS.

We also observe that a few of the respondents in CS who identified themselves as women strongly disagreed when asked whether they will do well in the course. This observation that a small population of women who have chosen to study computer science but think that they will perform poorly in the course is a mystery to us. We do not know of studies that would suggest that women are more likely than men to pursue careers that they do not believe they can succeed in (or vice versa).

To better contextualize the issue, the course that students who major in CS are attending is the very first course that they take at the University, and they respond to the question before starting the actual course. Students in other majors may take the course later in their studies. As such, other university studies or the content of the course should not influence the perceptions of the CS students. It is possible that orientation to studies, which students take part in during their first week at the university before classes, may influence students' perceptions. For example, as women are a minority in the studied context, and men have more programming experience, it may be that the discussions during the orientation may have influenced the perceived fit of women.

Within the country where the study was conducted, one could also argue that some may have signed up for computer science due to not being able to sign up for other more competitive subjects (e.g., medicine, law). The university in which this study took place allows students to pick minors (almost) freely and to reapply to other subjects next year. However, if a student enrolled in computer science to study other subjects, it is questionable whether they would attend the introductory programming course.

D. Limitations of Work

Our study comes with a range of limitations. First, we acknowledge both a sampling bias and a selection bias. The study has been conducted within a single university in one country, and the questionnaire was voluntary. This means that further studies are needed to assess both the external and internal validity of the study. We also did not ask for students' motivations, aspirations, or additional details about their backgrounds. As such, we do not know why the students have selected particular majors and why they have chosen to attend the introductory programming course – currently, we can only report the results, but do not claim to know the reasons for the results. Finally, in our survey, we did not collect

basic data such as race or ethnicity that would make it possible to study issues related to the double bind [36], and thus, cannot address them.

VI. Conclusions

In this work, we studied previous programming experience, performance, and self-efficacy of students on an introductory programming course. These factors were studied from the viewpoint of students' major and gender, contributing to the work seeking to understand the confidence gap.

Our answer to the first research question, *What are the previous programming experience differences between majors and genders?*, is as follows. Men in computer science have more previous programming experience than others, including women in computer science. There are no significant differences in previous programming experience between women in the studied subjects. Furthermore, there are no differences in previous programming experience between STEM and Other subjects.

Our answer to the second research question, *What are the performance differences between majors and genders?*, is as follows. Students in CS outperform students in other subjects, while there is no difference in students' performance in STEM and students in Others. This difference is visible when dividing the students by gender; men in CS outperform men in other subjects, and women in CS outperform women in other subjects. Simultaneously, there are no performance differences between men and women in CS, despite the difference in previous programming experience.

Our answer to the third research question, *What are the differences in self-efficacy between the majors and genders?*, is as follows. Within all majors, men are more confident in their ability to succeed in the course than women. Moreover, students in CS are more confident in their ability to succeed in the course than students in other subjects, while there is no difference between the confidence of students in STEM and Others. When comparing genders across the majors, men in CS are more confident in their ability to succeed in the course than men in other subjects. We did not observe a similar difference between women in CS and women in other subjects, and there is also no difference between women in CS and men in other subjects.

As a part of our current and future work, we are interviewing students from different majors to understand better their motivations, aspirations, background, and reasons for choosing a particular major, which may influence their behavior within CS courses. Furthermore, we are looking into interventions intended to improve students' sense of belonging within the campus and the academic community, and studying to what extent interventions on the sense of belonging influences students' performance and self-efficacy.

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