Increasing Students' Persistence in Computer Science through a Lightweight Scalable Intervention

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ABSTRACT

Research has shown that high self-assessment of ability, sense of belonging, and professional role confidence are crucial for students' persistence in computing. As grades in introductory computer science courses tend to be lower than other courses, it is essential to provide students with contextualized feedback about their performance in these courses. Giving students unambiguous and contextualized feedback is especially important during COVID when many classes have moved online and instructors and students have fewer opportunities to interact. In this study, we investigate the effect of a lightweight, scalable intervention where students received personalized, contextualized feedback from their instructors after two major assignments during the semester. After each intervention, we collected survey data to assess students' self-assessment of computing ability, sense of belonging, intentions to persist in computing, professional role confidence, and the likelihood of stating intention to pursue a major in computer science. To analyze the effectiveness of our intervention, we conducted linear regression and mediation analysis on student survey responses. Our results have shown that providing students with personalized feedback can significantly improve their self-assessment of computing ability, which will significantly improve their intentions to persist in computing. Furthermore, our results have demonstrated that our intervention can significantly improve students' sense of belonging, professional role confidence, and the likelihood of stating an intention to pursue a major in computer science.

CCS CONCEPTS

• **Social and professional topics → Women**; **CS1**.

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KEYWORDS

Positive Feedback, Introductory Computer Science, Persistence in Computing, Self-Assessment of Computing Ability

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1 INTRODUCTION

The U.S. is currently experiencing a shortage of computer science (CS) majors and computing professionals [17]. While many of the efforts to increase the number of CS majors focus on improving the academic performance of students, addressing their psychological needs may be just as important, if not more so, as research finds that students' beliefs about their academic ability [4], belonging [8], and their ability to meet professional roles [3] are all predictors of their persistence in STEM fields.

College is a new and uncertain time for students, both academically and socially. When choosing a major, students may feel: 1) uncertainty around their ability to academically succeed in a subject, 2) uncertainty around whether they belong in a major, and 3) uncertainty around their ability to meet the professional roles associated with a profession (i.e., whether they have the ability to successfully fulfill the roles, competencies, and identity features of a profession). This uncertainty may be reinforced in computer science classes and other STEM courses where average grades are lower than other university classes [1, 11, 16]. Students who have just started college might be uncertain about whether their performance can provide evidence for future success in STEM majors and careers. As a result, uncertainty around self-assessments of ability, belonging, and ability to meet professional roles may decrease the persistence of students in computing, thereby reducing the number of CS majors and computing professionals.

This study examines the effect of a lightweight email intervention designed to reduce students' uncertainty about their performance in computer science courses. This intervention is a positive, encouraging email sent from the professor to students in the treatment condition, in which the professor provides contextualized feedback about their grades. The goal of the intervention is to reduce students' uncertainty about their place within computer science and their computing performance. The pilot results of integrating this intervention in one CS1 classroom (193 students) has shown that the intervention positively influences self-assessment of computing for all students and intentions to persist for women [7]. In this study, we aim to confirm the effectiveness of our intervention by conducting a larger-scale study that spans over two semesters, three different introductory CS courses, and seven individual classrooms (892 students). More specifically, we examine the impact of this email intervention on students' self-assessments of ability, feelings of belonging in Computer Science, professional role confidence, and intentions to persist in computing. We then examine whether the intervention improves students' intentions to persist in computing because it positively impacts their psychological needs. During this study, we intend to answer the following research questions:

- RQ1. Does contextualized feedback improve students' self-assessment of computing ability?
- RQ2. Does contextualized feedback improve students' sense of belonging in computing fields?
- RQ3: Does contextualized feedback improve students' intentions to persist in computing fields?
- RQ4: Does contextualized feedback improve students' professional role confidence in computing-related careers?
- RQ5: Does contextualized feedback improve the likelihood for students to declare an intention to pursue a computer science major?
- RQ6. Does contextualized feedback improve students' intentions to persist in computing because it improves students' self-assessment of computing abilities?

To investigate these research questions, we conducted multiple linear regressions, logistic regression, and mediation analysis on data collected from multiple sections of three introductory computer science courses in Fall 2020 and Spring 2021. Our results indicate significant improvements in all psycho-social aspects (i.e., self-assessment of CS abilities, sense of belonging, etc.) under investigation in RQs 1-5 for students who received contextualized feedback. Furthermore, our mediation analysis confirmed the mediation effect of students' self-assessment of computing abilities on the relationship between receiving contextualized feedback and intentions to persist in computing fields (RQ6).

2 RELATED WORK

Research in computer science education has shown that high self-efficacy in computing is significantly related to students' intentions to persist. Self-efficacy is defined as one's belief in their ability to execute a task or achieve mastery in a particular domain [2]. Lishinksi et al. (2021) found that self-efficacy is the most important predictor for students' outcomes in a CS1 course [13]. They also found that female students modify their self-efficacy beliefs early in CS courses which could be one of the reasons that women are underrepresented in the CS major. Lewis et al. (2011) found that in CS specifically, the students judge their CS-ability based on previous

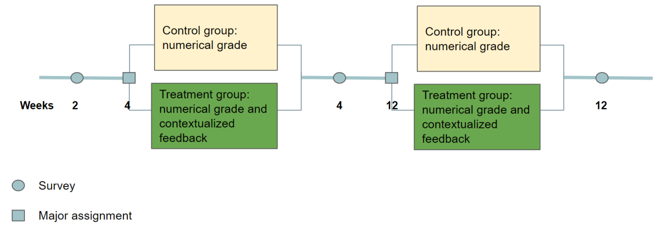

Figure 1: Study Timeline Over One Semester

CS experience, speed of programming, and grades [12]. Thus, an important factor contributing to CS self-efficacy is the students' self-assessment of their programming ability. In fact, some CS1 students negatively self-assess in response to the natural parts of the programming process [9]. Students that have more frequent negative self-assessments in their programming abilities tend to have lower self-efficacy in CS [10]. Therefore, increasing students' confidence in their programming skills may increase their self-assessment in CS abilities and thus increase their intentions to persist. There are many interventions in the literature to improve students' self-efficacy, such as peer instruction, growth-mindset training, goal-setting, and self-assessment [13].

Research has also shown that self-assessment can affect students' sense of belonging in CS and professional role confidence. In CS1, students often judge their performance with a self-critical bias, judging their own abilities more negatively than the abilities of another hypothetical student [11]. This biased self-assessment is even more intensified for women, as research has found that women rate themselves more negatively on scientific skills even when there are no differences in actual performance [6]. Therefore, CS instructors giving feedback to normalize the programming process of debugging, asking for help, and struggling could increase the students' self-assessment, which in turn will lead to an increase in their sense of belonging in CS. Furthermore, through several experimental studies, Correll has found that self-assessment of ability for students of both genders significantly affects the likelihood of them pursuing a computing-focused career [4, 5]. The positive perception of professional role confidence can then improve students' persistence in STEM-focused majors and occupations [3].

In this research, we aim to improve students' self-assessment of CS abilities by providing individualized, contextualized feedback at multiple points throughout the semester. As the literature suggests, this can have positive direct and indirect influences on students' intentions to persist and their actual persistence. Though we don't assess students' actual persistence in computing, we still can gain valuable insight by evaluating students' intentions to persist. According to research, intentions are the best predictors for future behavior outcomes [15]. Thus, measuring students' intentions to persist predicts students' actual persistence in STEM majors and careers. This research is promising because it shows that CS instructors have the opportunity to influence students' self-efficacy.

3 METHODS

We conducted a study in three introductory computer science courses at a large public university over two semesters (Fall 2020, Spring 2021). Students took three surveys to self-report their psycho-social attribute scores and received our intervention at two points in the semester. Figure 1 illustrates the study timeline over one semester.

3.1 Participants

892 students participated in our study, 409 in the first semester and 483 in the second. 51.1% (446) of the students were in their first year of university, and 72.5% (647) identified as men. Of the three courses, one course, CSC1Java, was a requirement for the computer science major at the university. The remaining two classes, CSC1Python and CSC1Matlab, were introductory computer science courses largely attended by non-computer-science students. 12.8% (114) of the students were enrolled in the CS-required course.

3.2 Intervention

At the beginning of the semester, a pre-survey was sent to each student in which students were asked to report: assessment of ability, intention to persist, role confidence, and belonging by completing questions on a Likert scale (e.g., “My ability in Computer Science is:” “Considerably below average” - “Considerably above average”). Demographic information such as major, number of computer science courses taken, GPA, the semester in college, age, race/ethnicity, gender, gender identity, sexual orientation, parents’ education, and parents’ occupation was also collected. The two other surveys sent during the semester collected the same information, with the exception of demographic information. Some professors required survey completion as part of the course grade, some offered extra credit for survey completion, and some did not offer students an incentive to complete the surveys.

Each professor identified two major assignments, typically in the 4th and 12th weeks of the semester, after which the students would receive feedback about their performance. Students were placed into three groups based on their grades. Top students had grades higher than the median assignment grade. Middle students had grades below the median but higher than a 72%. Bottom students scored a 72% or lower. After the first major assignment was graded, students were divided into intervention and control groups, stratified based on their gender, grade, and consent to have their data collected. 436 students were placed into the intervention group, and the remaining students were placed into the control group.

After each assignment, professors sent emails containing feedback about the grades. Students in the top and middle groups received emails congratulating them on their grades (e.g., “You got a grade% on the first test. Congratulations: you are a top performer in the class! You scored in the top ## percentile of all grades on this test! You received better than the median grade on the first test! Keep up the great work…”). Students in the bottom group received emails containing reassurance and advice to succeed (e.g., “You got a grade% on the first test. If you feel like this isn’t your best work, don’t fear. I have had tests that I did not do as well as I wanted to during my undergraduate years. I felt discouraged since it seemed like I understood everything going into that test. So I reached out, got help, and continued to work hard…”). Students in the control group received emails with no additional feedback (e.g., “We are distributing grades electronically this semester. You got a grade% on the first test.”). These emails also contained links to a follow-up survey.

Table 1: Self-reported psycho-social attribute scores statistics before the first interventions and after the last intervention for the intervention and the control group. Mean, standard deviation, and number of observations presented.

	Before		After	
	Intervention	Control	Intervention	Control
Assessment of Ability	N=328 4.354 (1.093)	N=348 4.350 (1.060)	N=328 5.119 (1.225)	N=348 4.898 (1.189)
Professional Role Confidence	N=326 2.387 (0.594)	N=347 2.394 (0.605)	N=326 2.682 (0.677)	N=347 2.571 (0.701)
Sense of Belonging	N=324 4.303 (0.874)	N=344 4.319 (0.873)	N=324 4.758 (0.933)	N=344 4.600 (0.957)
Intentions to Persist	N=328 3.134 (1.464)	N=347 3.184 (1.441)	N=328 3.570 (1.588)	N=348 3.308 (1.507)
Intentions to Pursue a CS Major	N=384 0.096 (0.295)	N=393 0.107 (0.309)	N=384 0.104 (0.306)	N=348 0.089 (0.285)

4 DATA

4.1 Controls

For our regression analyses (Tables 2 and 3), we controlled for the following variables:

- Course (CSC1Python, CSC1Matlab, CSC1Java)
  - The course the student was enrolled in during the study period
- Grade Average
  - The average of the two major assignment grades preceding surveys 2 and 3
- Initial Psycho-Social Attribute Values
  - The attribute values calculated from the first survey. Each of these was only paired with its corresponding final value.

4.2 Self-assessments of computing ability scale

For each survey, students indicated their agreement to each statement on a 7-point Likert scale (where 1 is “strongly disagree” and 7 is “strongly agree”):

(1) Computer Science is one of my best subjects.
(2) I get good grades in Computer Science.

Students also reported their own CS ability on a 7-point Likert scale where 1 is “considerably below average” and 7 is “considerably above average.” These two items constituted the self-assessment of CS scale which had an alpha of 0.90.

4.3 Professional role confidence scale

For each survey, students answered the question: "How confident has this Computer Science course made you in regards to the following:"

(1) Your development of useful skills.
(2) Advancing to the next level in Computer Science.
(3) Your ability to be successful in your career.
(4) That Computer Science is the right profession for you.
(5) That you can select the right sub-field of Computer Science.
(6) Your ability to find a satisfying job.
(7) Your commitment to Computer Science.

Confidence was indicated on a 4-point Likert scale where 1 is "not confident at all" and 4 is "highly confident." These 7 items were averaged together to create the professional role confidence scale which had an alpha of 0.90.

4.4 Sense of belonging scale

Students were asked: "Indicate to what extent you agree with the following statements regarding Computer Science at NCSU." and responded according to a 7-point Likert scale. Items for the sense of belonging scale include:

(1) I belong in Computer Science at NCSU.
(2) I feel comfortable in Computer Science at NCSU.
(3) Other people understand more than I do about what is going on in Computer Science at NCSU.
(4) I think in the same way as do people who do well in Computer Science at NCSU.
(5) It is a mystery to me how Computer Science at NCSU works.
(6) I feel alienated from Computer Science at NCSU.
(7) I fit in well in Computer Science at NCSU.
(8) Compared with most other Computer Science students at NCSU, I am similar to the kind of people who succeed in Computer Science.
(9) Compared with most other students at NCSU, I know how to do well in Computer Science.
(10) Compared with most other Computer Science students at NCSU, I get along well with people in Computer Science.

The sense of belonging scale constituted of these ten items and had an alpha of 0.87.

4.5 Intentions to persist in computing scale

Students were asked how likely they were to do each of the following on a 7-point Likert scale where 1 is "highly unlikely" and 7 is "highly likely.":

(1) Take another course in Computer Science.
(2) Get involved with undergraduate Computer Science research.
(3) Get involved with Computer Science clubs.
(4) Compete in a hackathon.
(5) Apply for a Computer Science internship.
(6) Minor in Computer Science
(7) Major in Computer Science.
(8) Apply to graduate School in Computer Science.
(9) Apply to graduate programs requiring high levels of Computer Science ability.
(10) Apply for jobs requiring high levels of Computer Science ability.

These 10 items constituted the intentions to persist scale with an alpha of 0.95. This scale is from [7] and is adapted from [5].

4.6 Intention to pursue a major in CS

Students were asked about their intended major as a short answer question. All responses referring to computer science (e.g., computer science, CS, etc.) were coded as one, and all other responses were coded as zero.

Table 1 shows the average and standard deviation of students' self-report of all of the scale before the first interventions and after the last intervention for the intervention and the control group.

5 ANALYSIS

We used four separate linear regression models to investigate the effect of our intervention on students' 1) self-assessment of computing ability, 2) sense of belonging in computing fields, 3) professional role confidence, and 4) intentions to persist in computing (RQs 1-4) respectively. The models used the intervention as the independent variable and the outcome (e.g., self-assessment) as the dependent variable while also controlling for students' class, average grade, and the initial self-reported score for the psycho-social outcome as additional independent variables. For each regression analysis, students who had missing values for any of the model variables were removed. The number of students used for each regression analysis is specified in Table 2.

We further implemented a logistic regression model to evaluate the effect of our intervention on the likelihood of students' stating an interest in pursuing a major in computer science [1], controlling for the same variables (average grade, class, and the initial self-reported score for the outcome under investigation). Any students with missing values for any of the model variables were removed (Table 3).

Finally, to answer RQ6, we conducted a mediation analysis [14] where we investigated the mediatory effect of self-assessment of CS ability on intentions to persist in computing for students who have received our intervention.

5.1 Effect of receiving contextualized feedback on students' self-perceptions and persistence in computing

Table 2 demonstrates the results of conducting the linear regression analysis to evaluate the effect of our intervention on the above-mentioned psycho-social outcomes, controlling for class, average grade, and self-reported initial score for the outcome under investigation. We found that our intervention significantly improved all four outcome variables: self-assessment of ability, sense of belonging, professional role confidence, and intentions to persist. As shown in Table 2 the improvement ranged from 4%-9% compared to students' average initial responses (Table 1).

[1] we used a logistic regression model here because this "intentions to persist" question was coded as a binary variable (1 for Computer Science/0 for other).

Table 2: Linear regression models predicting psycho-social attributes

	Self-Assessments of Ability	Sense of Belonging	Professional Role Confidence	CS Persistence
Intervention	.253***	.184***	.123**	.309***
	(.065)	(.050)	(.039)	(.079)
CSC1Python	-.151	.095	-.082	-.110
	(.126)	(.097)	(.076)	(.157)
CSC1Matlab	.147	.261**	.215**	.318*
	(.112)	(.085)	(.067)	(.138)
CSC11Java	-.055	.235*	.059	.345
	(.142)	(.003)	(.086)	(.138)
Grade Average (Time 2 and 3)	.061***	.029***	.016***	.025***
	(.004)	(.003)	(.002)	(.004)
Initial Self-Assessments of Ability	.441***	-	-	-
	(0.126)			
Initial Sense of Belonging	-	.647***	-	-
		(0.031)		
Initial Professional Role Confidence	-	-	.681***	-
			(.035)	
Initial CS Persistence	-	-	-	.752***
				(0.33)
Percentage Increase	5%	4%	5%	9%
N	676	668	673	675

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

5.2 Effects of our intervention on the likelihood of students stating an intention to pursue a major in CS

A logistic regression model was conducted to investigate the relationship between our intervention and the likelihood that a student states an intention to major in CS (RQ7). Our results in Table 3 demonstrated that when controlling for class, average grade, and initial likelihood to pursue a CS major, the odds of students stating an intention to pursue a major in CS increased by 130% for students' who received our intervention ($p < 0.05$).

When analyzing Q1-Q4, we note that, though significant, students' average grades have relatively smaller effect sizes on students' intentions to persist, compared to psycho-social constructs (e.g., sense of belonging in computing, self-assessment of computing abilities, etc.).

6 MEDIATORY EFFECT OF SELF-ASSESSMENT OF COMPUTING ON INTENTIONS TO PERSIST IN COMPUTING

We conducted a mediation analysis to investigate our intervention's direct and indirect effects on students' self-assessment of computing and their intentions to persist in computing. Our results (Figure 2) demonstrated that providing students with contextual feedback and encouragement significantly increased their self-assessment of computing ($p < .05$). The results further showed that the improvement in self-assessment of computing significantly improved students' intentions to persist in computing ($p < .001$) when controlling for class and average grade. Our results further confirmed the

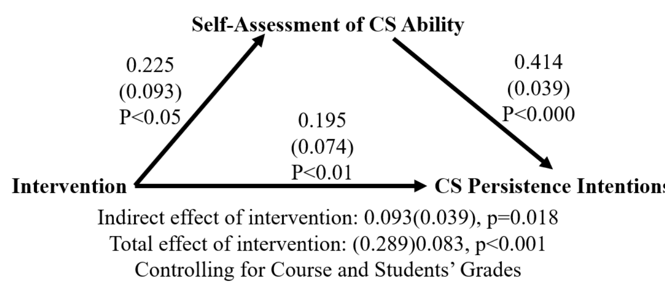

Figure 2: Mediation Analysis for Effect of Intervention on Self-Assessments of CS ability and CS Persistence Intentions

significant mediatory effect of the self-assessments of computing on the relationship between the intervention and students' intentions to persist in computing ($p < .01$) (RQ6). In other words, our intervention increased students' intentions to persist in computing as a direct result of the increase in their self-assessments of computing ability. This indirect effect of self-assessment of computing (0.093) amounts for 32% of the total effect of our intervention (0.289) in students' intentions to persist in computing.

7 DISCUSSION

Having a clear understanding of one's performance in a CS course is necessary for increasing students' persistence in challenging fields. This is especially important for STEM- and computing-focused fields where the grades tend to be lower than other college-level courses. Receiving contextual feedback that gives students a clear

Table 3: Logistic regression models predicting intent to major in CS at time 3

	Odds Ratio	Std. Error	z	P>|z|	[95% Conf.	Interval]
Treatment	2.334	0.962	2.06	0.040	1.040	5.236
Stated CS Major T1	101.418	63.071	7.43	0.000	29.975	343.141
CSC 111	0.204	0.176	-1.84	0.065	0.378	1.107
CSC 113	0.253	0.145	-2.40	0.016	0.082	0.778
CSC 116	0.865	0.573	-0.22	0.826	0.236	3.169
Average of grades 1 and 2	1.063	0.022	2.99	0.003	1.021	1.106
_cons	2.000e-4	3.000e-4	-4.34	0.000	3.370e-06	0.009

n=777 observations

understanding of their relative performance in the course can improve students' intentions to persist, and thus, their persistence, especially for high-achieving students. Providing students with contextualized feedback is even more crucial during COVID time when many courses are being offered online or hybrid, reducing the opportunities for face-to-face interactions with instructors and receiving direct feedback.

In this study, we investigated the effect of a lightweight, scalable intervention where instructors sent students individualized and contextualized feedback about their performance in the course. While high-achieving students received endorsement and encouragement to further engage with CS-focused activities, low-performing students were offered support, resources, and encouragement for improving their efforts. **Our results demonstrated that this lightweight intervention significantly enhanced students' self-assessment of CS ability, which improved students' intentions to persist in computing fields** even when controlled for performance (average grades). Furthermore, **students who received the automated feedback showed significant improvements in their sense of belonging, professional role confidence, and likelihood that they state an intention to pursue a major in computer science** (controlling for class, average grade, and their initial self-reported score for the psycho-social outcome). Though the magnitudes of effect were small, our intervention succeeded in **significantly improving students' experience in introductory CS courses across all classes, initial computing-focused psycho-social scores, and performance**. This intervention can be readily adapted by instructors across all introductory computer science courses at different institutions to improve students' experience, self-efficacy, and persistence.

8 CONCLUSION AND FUTURE WORK

In this paper, we presented the results of a lightweight, scalable intervention to improve students' perception of their performance in introductory CS courses. Results of conducting multiple linear regressions demonstrated a significant improvement in students' self-assessment of ability, sense of belonging, professional role confidence, and intentions to persist in computing. Furthermore, a logistic regression analysis demonstrated that our intervention significantly increased the likelihood that students would declare an intention to pursue a major in CS. Finally, a median analysis revealed that students' increase in self-assessment of computing ability explains 32% of growth in their intentions to persist in computing. While the effect sizes were small, our results showed significant improvement in students' self-efficacy and persistence for all students regardless of their initial self-efficacy and persistence intention scores, their average grades, and the class where they received this intervention. This intervention can be adapted by many instructors in CS introductory courses to improve students' experience, particularly during COVID.

The results reported for this study are based on data collected from two semesters. We plan to integrate data from two further semesters and conduct linear hierarchical models to account for variation in the data, including semester and instructor. We will also collect CS enrollment data for consented students to measure students' actual persistence in computing. Data collected from students' interviews will be analyzed to reveal the results obtained through statistical analysis.

9 THREATS TO VALIDITY

These data were collected during the COVID period, where classes were offered either online or hybrid classes. The extraordinary circumstances under which the data were collected are expected to affect the results. For example, under normal circumstances, results might show a significantly higher effect of the intervention on women and underrepresented students' intentions to persist compared to other students [7]. In contrast, under COVID, all the students seem to benefit from our intervention alike.

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