NUDGES AREN'T ENOUGH!

MEASURING AND INFLUENCING SELF-EFFICACY AND BELONGINGNESS OF STUDENTS IN INTRODUCTORY COMPUTER SCIENCE COURSES

HCI MASTER'S PROJECT – SPRING 2018

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1. INTRODUCTION

Success in entry level programming courses (CS1) often determines whether a student will continue to pursue a computer related major. Prior work suggests that many factors may influence success within CS courses including previous computing experience [1], comfort level [2], mathematics or science background [3], computer self-efficacy [4], and feelings of belongingness [5].

This study aims to further investigate the relationship between self-efficacy and belongingness within online and in-person versions of a CS1 course. Additionally, an intervention ("nudge") to promote belongingness within the space is conducted and its effects are evaluated.

1.1 RESEARCH QUESTIONS

RQ1: How do self-efficacy and belongingness influence CS1 performance?

RQ2: Can brief psychological interventions increase feelings of belongingness in CS1?

RQ3: How do online vs in-person class environments influence self-efficacy and belongingness in CS1?

2. PRIOR RESEARCH

2.1 SELF-EFFICACY IN COMPUTING SCIENCE EDUCATION

Self-efficacy is defined as "people's judgements of their capabilities to organize and execute courses of action required to attain designated types of performance" [6] By influencing effort and coping strategies, self-efficacy is important when considering learning outcomes [6]. It has been found that self-efficacy increases throughout CS1 courses; however, women initially have lower levels of self-efficacy in this domain [7]. Increases in self-efficacy have been shown to be positively associated with course grades [8] and have been shown to be the strongest predictor of performance in CS1 courses [9]. However, other studies have shown self-efficacy to not be significantly related to CS1 course performance [10].

Course design recommendations have been offered in order to increase self-efficacy of students. These include offering frequent assignments with ample feedback as opposed to longer, less frequent assignments [7] and providing aggregate peer data to show relative performance [11].

2.2 Belongingness in educational domains

The need to belong is a fundamental human desire [12] and influences academic choices and performance [13]. It is well known that stereotypical clues can encourage or deter the involvement of different races and genders in many areas, including computer science [5]. Prior work has implemented interventions to increase the belongingness of people in academic spaces. Some studies suggest that listing the names of family and friends who participate in a field can cause increased feelings of belongingness; however, in instances where a person cannot list many names, this intervention can become detrimental and cause decreased feelings of belongingness [14]. Other interventions have had participants write letters to pen-pals encouraging a growth mindset [15] and responding to prompts that require them to connect their personal values to the subject in question [16].

3. Methodology

3.1 Participants

Students enrolled in two sections (online and in-person) of a Python CS1 course at a public university took part in this study. Students were undergraduates majoring from a variety of non-engineering majors including computer science, mathematics, and business administration. Exams and homework of the online and in-person courses were different; however, each course had three exams that were administered during the same weeks of the semester.

3. 2 Materials

3.2.1 Surveys

Prior validated surveys of self-efficacy [17] and belongingness [13] were slightly modified and aggregated to form the single instrument used in this study. The original self-efficacy survey asked questions related to C++ and these were changed to ask about Python. The belongingness survey originally centered around mathematics and was changed to reflect a computer science context. Each of the surveys asked questions in a 7-point Likert format. The survey in its entirety is included in the appendix.

Each of the surveys were used to compute overall scores of belongingness and self-efficacy. The belongingness survey contains five categories of questions: membership (questions 1-4), acceptance (questions 5-14), affect (15-22), desire to fade (questions 23-26), and trust (questions 27-30). The overall belongingness score is the average of the averages of each category. Questions 5,8,10,12,14,16,18,19,22,23,24, and 26 were negatively coded when computing averages. The maximum overall belongingness score possible is a 7. The overall self-efficacy score was computed as the sum of all Likert answers; therefore, the maximum overall self-efficacy score for the 26-question survey is a 182.

3.2.1 Interventions

Two sets of four prompts each were created and administered. One set of prompts was focused on connecting personal values to computer science while the other set dealt with providing study tips to new college students. The third prompt of each of the interventions had the student respond to a crafted testimony of a hypothetical student. In one passage, a student did not feel as if they belonged in computer science and in the other the student was struggling with studying in college. All prompts are included in the appendix.

4. Procedure

The study was conducted over a fifteen-week semester in three parts, the first part in the second week of the semester, the second part over the eighth to twelfth weeks, and the third part during the thirteenth week. Figure 1 displays the timeline of the study.

In the first part of the study, students completed the self-efficacy and belongingness survey. This resulted in pre-course self-efficacy and belongingness scores.

In the second part, of the students who completed the pre-course survey, students were randomly and evenly separated into two experimental groups. One group received four value-driven prompts while the other received four generic prompts. They were given a week to respond to the prompts and freedom in the level of detail of their responses. All prompts and prompt responses were administered over email.

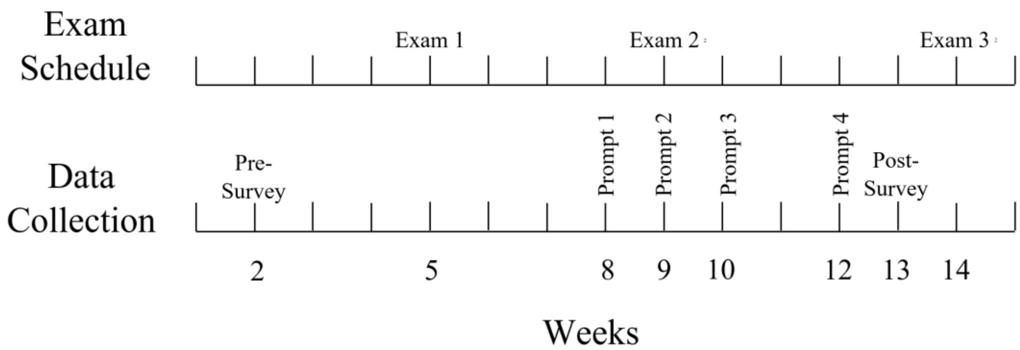

Figure 1: Timeline of research study

The third part involved collecting student responses to the self-efficacy and belongingness survey at the end of the course. This resulted in post-course self-efficacy and belongingness scores.

5. RESULTS

5.1 PRE-COURSE SURVEY RESULTS

The pre-course survey was administered and a total of 95 students responded. Demographics of the respondents are shown in Table 1

Class Type	Online class: 54
	In-person class: 41
Gender	Male:51
	Female: 44
Race	Asian: 30
	Black: 2
	Hispanic: 2
	Multiracial: 10
	White: 51

Table 1: Pre-course survey respondent demographics

Due to the small amount of racial diversity of the sample, analyses based on race were not considered. Instead, analyses were centered around gender, and class type. Pre-course self-efficacy ($\bar{x}$ = 105.84, σ = 34.32) and belongingness ($\bar{x}$ = 4.55, σ = 0.85) scores of women were lower than the pre-course self-efficacy ($\bar{x}$ = 109.33 σ = 34.54) and belongingness ($\bar{x}$ = 4.73, σ =

0.91) scores of men (Table 2). Differences in self-efficacy (p = 0.826) and belongingness (p = 0.782) by gender were not significant.

	Gender	N	Mean	Std. Deviation	S.E. Mean
Pre_belong	Male	51	4.73	.91	.13
	Female	43	4.55	.85	.13
Pre_efficacy	Male	51	109.33	34.54	4.84
	Female	43	105.84	34.32	5.23

Table 2: Pre-course belongingness and self-efficacy by gender

Students enrolled in the online course had pre-course self-efficacy ($\bar{x}$ = 99.31, σ = 38.63) and belongingness ($\bar{x}$ = 4.66, σ = 0.94) scores lower than the pre-course self-efficacy ($\bar{x}$ = 117.15, σ = 26.25) and belongingness ($\bar{x}$ = 4.60, σ = 0.81) scores of students enrolled in the in-person course (Table 3). By class type, differences in self-efficacy were significant (p = 0.002), but differences in belongingness were not (p = 0.348).

	Class	N	Mean	Std. Deviation	S.E. Mean
Pre_belong	Online	54	4.66	.94	.13
	Person	41	4.60	.81	.13
Pre_efficacy	Online	54	99.31	38.63	5.26
	Person	41	117.15	26.25	4.10

Table 3: Pre-course belongingness and self-efficacy by class type

Since interventions did not begin until after the first test, analyses on the influence of pre-course self-efficacy and belongingness on Test 1 of each course can be considered. In the online course, pre-course self-efficacy had a non-significant, positive correlation (p = 0.356, r = 0.13) with Test 1 performance and belongingness had a significant, positive correlation (p = 0.007, r = 0.37) with Test 1 performance (Table 4) .

		Test1	Pre_belong	Pre_efficacy
Test1	Pearson Correlation	1.00	*.37*	.13
	Sig. (2-tailed)		.007	.356
	N	52	52	52
Pre_belong	Pearson Correlation	*.37*	1.00	*.53*
	Sig. (2-tailed)	.007		.000
	N	52	54	54
Pre_efficacy	Pearson Correlation	.13	*.53*	1.00
	Sig. (2-tailed)	.356	.000	
	N	52	54	54

Table 4: Pre-course belongingness and self-efficacy correlation with Test 1 (Online course)

In the in-person course, pre-course self-efficacy had a non-significant, positive correlation ($p = 0.693$, $r = 0.06$) with Test 1 performance and belongingness had a non-significant, positive correlation ($p = 0.056$, $r = 0.3$) with Test 1 performance (Table 5).

		Test1	Pre_belong	Pre_efficacy
Test1	Pearson Correlation	1.00	.30	.06
	Sig. (2-tailed)		.056	.693
	N	40	40	40
Pre_belong	Pearson Correlation	.30	1.00	.14
	Sig. (2-tailed)	.056		.389
	N	40	41	41
Pre_efficacy	Pearson Correlation	.06	.14	1.00
	Sig. (2-tailed)	.693	.389	
	N	40	41	41

Table 5:Pre-course belongingness and self-efficacy correlation with Test 1 (In-person course)

5.2 Intervention Results

Of the students who completed the pre-course survey, students were randomly assigned to two experimental groups. Table 6 shows the demographic breakdown of each of the groups.

		Group 1: Value Driven Prompts *N = 48*	**Group 2: Generic Prompts** *N = 47*
Class Type	Online class	27	27
	In-person class	21	20
Gender	Male	25	26
	Female	23	21

Table 6: Experimental group demographic breakdown

To analyze the effects of the intervention, post-course self-efficacy and belongingness scores can be considered. Of the initial 95 students who completed the pre-course survey, 24 also completed the post-course survey. Of these 24 students, 10 had been a part of the value-driven prompt group while 14 were in the generic prompt group. Tables 7 and 8 show the interaction between the number and type of prompts answers and the change in belongingness and self-efficacy.

Generic Prompts	# Prompt Resp.	N	Mean	p
Change in Belongingness	0	5	0.42	0.049*
	1	3	-0.85	
	4	6	0.06	
Change in Self-efficacy	0	5	13	0.781
	1	3	3.33	
	4	6	29.00	

Table 7: Generic Prompt Group Survey Differences by Number of Interventions

Value-Driven Prompts	# Prompt Resp.	N	Mean	p
Change in Belongingness	0	4	0.25	0.469
	1	3	-0.36	
	4	3	-0.13	
Change in Self-efficacy	0	4	26.25	0.35
	1	3	44.33	
	4	3	31	

Table 8: Generic Prompt Group Survey Differences by Number of Interventions

The hypothesis of the intervention was that only value-driven prompts would increase belongingness. However, of the people who completed any value-driven prompts, their belongingness scores decreased on average. Additionally, of the people who completed generic prompts, their belongness scores decreased or only slightly increased. Changes in self-efficacy are natural throughout the course as students learn more than they had known at the start of the course. Figure 2 shows an aggregated view of change in belonginess per experimental group for all number of prompts responded to. On average, only those within the in-person course that were presented generic prompts had any increase in belongingness throughout the course. There were no statistically significant differences in the changes in belongingness and self-efficacy between genders for either course.

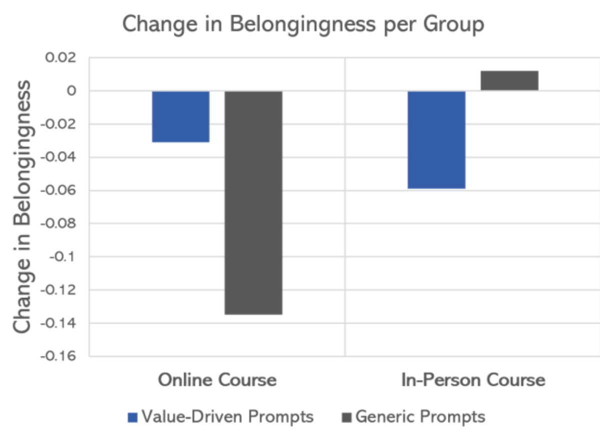

Figure 2: Change in belongingness per experimental group, per class

5.3 Course Design Effects

There were 9 students overall who completed both the pre-course and post-course surveys but did not respond to any of the intervention prompts—3 in the online course and 6 in the in-person course. From analyzing just these students' self-efficacy and belongingness changes, information can be inferred about the influences of the course designs themselves. Table 9 displays the average change in belongingness and self-efficacy of the students who did not complete any of the interventions. Both class types had increased belongingness and self-efficacy; however, their differences are not significant. This suggests that both course designs produce similar effects in these areas even with the differences in exams, homework, and class structure.

	Class	N	Mean	p
Change in Belongingness	Online	3	0.32	0.935
	Person	6	0.35	
Change in Self-efficacy	Online	3	21.00	0.791
	Person	6	17.83	

Table 7: Average change in belongingness and self-efficacy per class type

Discussion

Even as our world becomes inundated with technology, we still know relatively little about how people learn computer science as compared to other fields. Moreover, as the rates of students enrolling in computer science courses increases, it is becoming a higher priority to design courses that not only educate students but also allow them to feel as if they belong in the space and can succeed. This study examined the influence of two CS1 courses and brief interventions on self-efficacy and belongingness of students.

RQ1: How do self-efficacy and belongingness influence CS1 performance?

It was found that initial self-efficacy and belonginess of women in CS1 courses is lower than that of men. This is consistent with prior research that shows that men initially overestimate their abilities and then proceed through a calibration process throughout the course [7]. Moreover, initial self-efficacy was found to be positively correlated with initial test performance, and test performance can have lasting effects on how people view their abilities in a certain area.

RQ2: Can brief psychological interventions increase feelings of belongingness in CS1?

On average, feelings of belongingness decreased among participants no matter their gender or intervention type. This suggests that brief nudges are not enough when trying to cause students to change their beliefs and mindsets in computer science. This result has been echoed in previous research [17] as growth mindset interventions have not worked in computer science courses. However, feelings of belongingness did slightly increase on average for the participants who did not participate in the intervention. Prior research [14] has shown that there is a tipping point in psychological nudges that can cause them to change from being beneficial to detrimental.

However, even those students who only responded to one prompt had a decrease in belongingness. It is improbable that the point of diminishing returns for this type of intervention is the presence of the intervention at all. Therefore, future work would need to be conducted in order to further understand why these nudges had negative outcomes.

RQ3: How do online vs in-person class environments influence self-efficacy and belongingness in CS1?

When examining students who did not interact with the interventions, differences between class type were not significant. The online course is composed of many design features to greatly increase the learning outcomes of students. Lecture videos are in manageable chunks that can easily be repeated, exercises and homework can be attempted unlimited times until a correct answer is produced, and exams are taken remotely in whatever environment the student desires. On average, grades in the online course are higher than those in the in-person version. The creator of the online course attributes this increased performance to the aforementioned design changes rather than any change in content difficulty. Therefore, given the comparative increase in performance between the class types, it could be hypothesized that students would exit the online version of the course with higher levels of self-efficacy and belongingness than in the in-person. However, this does not seem to be the case. This raises further questions of how a course can produce better learning outcomes but not greatly increase feelings of belongingness. This suggests that different structural changes must be implemented in order to significantly change feelings of belongingness of students.

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Appendix

Self-Efficacy and Belongingness Survey

Today we have some questions we would like you to answer about your experience with computer science courses and in the computer science academic community. When we mention the computer science academic community, we are referring to the broad group of people involved in that field, including the students in a computer science course. We would like you to consider your membership in the computer science community. Given this broad definition of belonging to the computer science community, please respond to the following statements based on how you feel about that group, your membership in it, and your skills. There are no right or wrong answers to any of these statements; we are interested in your honest reactions and opinions. Please read each statement carefully, and indicate the number that reflects your degree of agreement.

Part 1

Not Confident at All			**Neutral**			**Absolutely Confident**
1	**2**	**3**	**4**	**5**	**6**	**7**

1. I can write syntactically correct Python statements
2. I understand the language structure of Python and the usage of the reserved words.
3. I can write logically correct blocks of code using Python
4. I can write a Python program that computes the average of any given number of values
5. I can use built-in functions that are available in the various Python libraries
6. I can write a small Python program given a small problem that is familiar to me
7. I can write a reasonably sized Python program that can solve a problem that is only vaguely familiar to me
8. I can write a long and complex Python program to solve any given problem as long as the specifications are clearly defined
9. I can organize and design my program in a modular manner
10. I can make use of a pre-written function, given a clearly labeled declaration of the function
11. I can debug (correct all the errors) a long and complex program that I had written and make it work.
12. I can comprehend a long, complex multi-file program.
13. I could complete a programming project if someone showed me how to solve the problem first
14. I could complete a programming project if I had only the language reference manual for help.
15. I could complete a programming project if I could call someone for help if I got stuck.
16. I could complete a programming project once someone else helped me get started.
17. I could complete a programming project if I had a lot of time to complete the program.
18. I could complete a programming project if I had just the built-in help facility for assistance.

19. I could find ways of overcoming the problem if I got stuck at a point while working on a programming project
20. I could come up with a suitable strategy for a given programming project in a short time.
21. I could manage my time efficiently if I had a pressing deadline on a programming project
22. I could mentally trace through the execution of a long, complex, multi-file program given to me
23. I could rewrite lengthy confusing portions of code to be more readable and clear.
24. I can find a way to concentrate on my program, even when there were many distractions around me
25. I can find ways of motivating myself to program, even if the problem area was of no interest to me.
26. I could write a program that someone else could comprehend and add features to at a later date

Part 2

Strongly Disagree			**Neutral**			**Strongly Agree**
1	**2**	**3**	**4**	**5**	**6**	**7**

<u>When I am in a computer science setting:</u>

1. I feel that I belong to the computer science community.
2. I consider myself a member of the computer science world.
3. I feel like I am part of the computer science community.
4. I feel a connection with the computer science community.
5. I feel like an outsider.
6. I feel accepted.
7. I feel respected.
8. I feel disregarded.
9. I feel valued.
10. I feel neglected.
11. I feel appreciated.
12. I feel excluded.
13. I feel like I fit in.
14. I feel insignificant.
15. I feel at ease.
16. I feel anxious.
17. I feel comfortable.
18. I feel tense.
19. I feel nervous.
20. I feel content.
21. I feel calm.
22. I feel inadequate.
23. I wish I could fade into the background and not be noticed.

Intervention Prompts

Prompt 1

Value Driven	Generic
What is something that you are passionate about or really interested in, and how could computer science help you in this area?	What is the best study advice you could give to an incoming student?

Prompt 2

Value Driven	Generic
Describe a time during this CS class when you have been proud of yourself.	Describe the aspect of college life that you enjoy the most.

Prompt 3

Value Driven	Generic
Read the following testimony and provide any type of response you would like. "I had never coded before coming to college. I had done some HTML/CSS but never actual coding. I chose computer science because I heard there would be a lot of jobs and the pay was high. Honestly, when I took my first CS course, I was scared. It seemed like everyone else had coded before and understood everything before the professor even explained it. I was kind of an outsider. I did okay on my first test, but I really wanted to get an A. I utilized every resource available and eventually did very well. The funny thing about it all was that the same people I was intimidated by at first were the same people I began to help towards the end of the class. Sometimes the culture in CS can be very daunting, but I now know I'm just as good as everyone else and I belong here."	Read the following testimony and provide any type of response you would like. "College is a crazy place. There are so many different people, so many things to do, and no one is there making sure you go to class. When I came to college I knew I wanted to be a part of Greek life because I wanted a chance to meet a bunch of people and break out of my nerdy shell. I became too involved in too many clubs and activities and my grades suffered. I did so well in high school without really trying, but this doesn't seem to be the case in college. I currently in the process of trying to balance everything and get my life together, so we will see how this goes. "

Prompt 4

Value Driven	Generic
So far in the class, what do you think has been the most meaningful concept or assignment in relation to your future goals?	Have your studying/note-taking strategies in this computer science course differed from other classes? If so, how?