Formal research experiences for first year students: A key to greater diversity in computing?

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ABSTRACT

Underrepresented students in computing (women and non-White/non-Asian men) are known to feel a weaker sense of belonging than majority students (Asian/White men). This difference is important because a low sense of belonging can lead to disengagement and attrition in education settings. In the current study, we assessed whether and how early formal research experience might narrow this gap in sense of belonging. The sample for this study derives from a longitudinal study on undergraduate students affiliated with computing departments across the United States. We used propensity scores to generate an appropriate sub-sample of students to compare against formal research participants (n = 110 formal research students; n = 110 students with no formal research experience). We found formal research experience during students' first year was associated with a strong sense of mentor support during their second year. Perceived mentor support predicted a strong sense of belonging for underrepresented students, but not majority students. Importantly, the typical gap in sense of belonging among underrepresented and majority students disappeared among students with high mentor support. Our work suggests that formal research, when introduced early, might promote greater diversity in computing in the long term. We present a model for early undergraduate research, and resources for readers who wish to adopt the model.

CCS CONCEPTS

• **Social and professional topics → Informal education**; **Model curricula**;

KEYWORDS

undergraduate research, mentorship, sense of belonging, underrepresented students

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1 INTRODUCTION

Meaningful, formal research experience is known to benefit undergraduate students. However, formal research experiences are rarely offered to lower division students. We suspect elements of formal research that are part and parcel to the experience (e.g., mentorship) may benefit students who are particularly likely to wonder whether or not they belong in computing, namely, lower division students whose gender and/or race are underrepresented in computing[1]. We conducted a longitudinal study on students during their first few years of college; we measured the degree to which (a) formal research fosters a strong sense of mentor support, and (b) mentor support fosters a sense of belonging in the computing community – particularly among underrepresented students. At the end of the paper, we present a model for early undergraduate research and resources for readers who wish to adopt that model.

1.1 Formal research: A conduit to mentorship and support

Research points to benefits of formal research experiences on undergraduate students ranging from building critical thinking and problem solving skills to motivating students to pursue graduate work [14, 16, 18, 23, 24]. Of particular interest for the current work is the impact of formal research on students' access to mentorship and the sense that students feel supported by successful individuals in the research community. Research indicates that formal research experiences allow students to develop strong relationships with mentors and other professionals, and become integrated into the discipline's culture [19, 24]. Further, formal research experiences integrate students into a professional community allowing them to develop a sense of belonging in the discipline [14]. Thus, formal research experiences provide mentorship and support, which we suspect may be particularly beneficial for lower division underrepresented students' persistence in computing.

1.2 The importance of a sense of belonging in academic settings

A sense of belonging is defined as the subjective feeling of fitting in and being included as a valued and legitimate member in a particular setting, such as a learning environment [7, 10, 11, 31]. Students' sense of belonging is a robust predictor of academic motivation, engagement, and achievement in education settings [10, 12, 20, 26, 31, 33]. Regrettably, recent research indicates underrepresented groups tend to feel a lower sense of belonging in computing than majority groups [8, 15, 27]. Thus, it is particularly important to

[1] We refer to White and/or Asian men as the "majority" and all others as "underrepresented" [17].

understand how to shape and fortify underrepresented students' sense of belonging in computing education settings.

1.3 Belonging uncertainty

Walton and Cohen [30] propose that students who are members of underrepresented and stigmatized groups experience uncertainty as to whether they belong (i.e., "belonging uncertainty"), which can lead to sensitivity to, and biased interpretation of, ambiguous information. For instance, receiving a poor exam grade becomes evidence of general incompetence, and an unfriendly lab partner indicates one's group is not welcome in general. Similarly, Hughes and colleagues [13] argue that students most at risk of failure in an academic setting will be most affected by their subjective experiences in that setting – the authors call this the "vulnerability hypothesis."

Several studies have documented underrepresented groups' sensitivity to subjective experiences in computing and other quantitative education settings. In one study, Walton and Cohen [30] found that African American undergraduate students who were reminded they have few friends in computer science were more pessimistic about their potential for success in the field; the same reminder had no effect on White students' perceptions of their potential to succeed. Other research indicates women first-generation college students' sense of belonging in introductory computing courses is positively related to in-class interaction with faculty; the same is not true for their peers [8]. Further, calculus students' perceptions that others believe (a) math ability is an innate trait and (b) the stereotype that women have less of this ability than men led women, but not men, to experience a low sense of belonging in math [10].

We utilize theory and research on the pliant nature of underrepresented students' sense of belonging in computing and quantitative fields to make the following prediction: underrepresented students' perceptions that they are supported by mentors in their computing department will be strongly related to their sense of belonging in the computing community. For majority students, we expect a weaker or non-existent relationship between mentor support and sense of belonging in computing.

1.4 Study Overview and Contributions

The current work makes two contributions to education research. First, we study the long-term impact of early formal research on computing students. We are aware of no other education research that has focused on the benefits of formal research on lower division students. Furthermore, very little research has looked at the benefits of formal research over time[2]. To address this gap in the literature, the current work uses a longitudinal research design to assess the impact of formal research on lower divisions students' progression through college (see Appendix, Table 1 for longitudinal design).

Second, we know of no research that has examined the reason(s) why formal research may have long-term positive impact on underrepresented students' academic trajectory. We test whether mentor support, obtained through formal research experiences, enhances underrepresented students' sense of belonging in computing.

[2] See [24] for an exception, but note that we are looking specifically at computing students, which is not the focus of [24]

The following questions guide our inquiry:

(1) Does early formal research predict stronger perceptions of mentor support?
(2) Does mentor support predict a strong sense of belonging in computing? Is this true for underrepresented and majority students?

2 METHOD

2.1 Longitudinal method

The sample for this study derives from a national annual survey initiative for undergraduate students affiliated with computing[3]. This survey initiative is run by The Computing Research Association's Center for Evaluating the Research Pipeline (CERP)[4]. Two cohorts of computing students were invited to complete an initial online survey about their experiences as computing students, and were contacted one year later to complete a second, similar survey. This type of research design, called a "longitudinal panel', collects data from multiple cohorts over multiple years. This design provides large sample sizes when data are aggregated across cohorts, thereby allowing for analyses on subpopulations (e.g., second year students), and alleviating the impact of respondent attrition on statistical power [6].

The first cohort of students (cohort 1) received their initial survey invitation in 2014, and the second cohort of students (cohort 2) received their initial survey invitation in 2015. Department faculty and/or other personnel distributed the initial online survey link[5].

At the end of the initial survey, students were asked if they consented to being tracked over time as part of a longitudinal study. Consenting students were sent a second survey one year later (in 2015 for cohort 1, and 2016 for cohort 2). Data from the initial and follow up surveys for both cohorts 1 and 2 were merged into a single, longitudinal dataset.

2.2 Sample

There were 10,169 undergraduate students who responded to the initial survey (i.e., 2014 and 2015 academic years combined). Of those students, 6,171 (61%) agreed to be contacted for follow-up. When contacted one year later for follow up, 2,471 (40%) completed the survey.

We restricted the sample to include only students who were computing majors and enrolled in their second year of college during the initial wave of data collection (n = 698). This would allow us to measure (a) whether students had previously completed formal research during their first year (via retrospective reporting), (b) students' sense of mentor support during their second year of college, and (c) students' sense of belonging in computing during the third

[3] "Affiliation" includes computing majors/minors or students enrolled in computing courses. "Computing" includes fields with a strong computing component (e.g., computer science, computer engineering, bioinformatics).
[4] In 2015, researchers at the University of California Los Angeles also distributed CERP's annual survey to a sample of universities (n = 13; 8% non-doctoral granting). These data are included in the 2015 sample discussed in this paper.
[5] In 2014, 92 departments distributed the CERP survey to their students (34% non-doctoral granting institutions). In 2015, 93 departments distributed the CERP survey to their students (27% non-doctoral granting institutions).

year of college. See Table 1 in the Appendix for our longitudinal design.

We then restricted our sample to students with complete data for all measures and relevant demographic information (gender and race/ethnicity). The final sample was n = 549. Within our final sample, n = 113 (21%) students had participated in a formal research program during their first year in college. We used propensity scores to generate an appropriate sub-sample of students to compare against formal research participants. Propensity score matching is an analytic technique that "matches" individuals in a treatment group (e.g., formal research participants) to individuals from a comparison group (e.g., non-participants) who are as comparable as possible on a set of relevant individual-level characteristics [2, 3, 25]. Thus, propensity score matching controls for the role of student-level variables (e.g., being a first generation college student) that might otherwise explain outcome variables (e.g., sense of belonging in computing) rather than the "treatment" (e.g., formal research participation). The propensity score matching variables used in this study were indicators for: underrepresented status (0 = no, 1 = yes), first generation college students status (0 = no, 1 = yes), U.S. citizenship status (0 = no, 1 = yes), whether or not students had attended community college (0 = no, 1 = yes), and highest degree granted by students' current department (1 = Ph.D., 2 = M.S., 3 = B.S.). Of the 113 formal research participants, 3 students were unable to be matched[6], resulting in a final sample of 110 formal research participants and 110 comparison group students. The demographic characteristics relating to gender and race for the resulting sample are shown in Table 2 in the Appendix.

2.3 Measures

2.3.1 Formal research question. To measure whether students had participated in formal research during their first year in college, we used data from the following question on the initial survey: Since September 2014 (2015 for cohort 2), have you participated in any "formal" research experiences? Formal research includes an experience you applied for, and through which you worked closely with a mentor or research advisor. Students then indicated whether they had or had not participated in such an experience during the time-frame given.

2.3.2 Mentor support. To measure students' perceptions of mentor support during their second year of college, we used data from four items on the initial CERP survey (e.g., To what extent do you have a mentor who helps you improve your computing skills?), using a scale ranging from (1) not at all to (5) very much. These four items formed a reliable construct (Cronbach's alpha [α] = .90), so we created an aggregate score that was the mean of the four items. See Table 3 in the Appendix for all four questions.

2.3.3 Sense of belonging. Three items assessed students' sense of belonging in the computing community on the initial and follow up survey (e.g., I feel like I "belong" in computing), using a scale ranging from (1) strongly disagree to (5) strongly agree. These items formed a reliable construct (initial survey α = .77, follow up survey α = .81), so we created aggregate scores, which were the mean of the items. See Table 3 in the Appendix for all three questions.

[6]Failure to match all cases is common; for more information, see [2, 3].

3 RESULTS

We present our analyses organized by research question. We refer to data collected in the initial survey as "wave 1" and data collected in the follow up survey as "wave 2".

3.1 Does early formal research predict stronger perceptions of mentor support?

To address our first research question, we ran a one-way analysis of variance treating mentor support as a dependent variable, and involvement in formal research as a between subjects independent variable (both from the wave 1 survey). We found that students who reported having participated in formal research during their first year also reported a stronger sense of mentor support during their second year (formal research mean [M] = 3.03, standard deviation [SD] = 1.15, no formal research M = 2.40, SD = 1.26), $F(1,219)$ = 15.07, $p \leq .01$.

3.2 Does strong mentor support predict a strong sense of belonging? Is this true for underrepresented and majority students?

Having found that formal research predicts stronger perceptions of mentor support, we next tested whether perceptions of mentor support might narrow the gap between underrepresented and majority students' sense of belonging in computing. To do so, we ran a multiple regression model regressing students' sense of belonging at wave 2 on students' sense of mentor support at wave 1 (mean centered, continuous), underrepresented status (dichotomous), the interaction between mentor support and underrepresented status, and students' sense of belonging at wave 1 (mean centered, continuous). We controlled for students' sense of belonging at wave 1 in order to measure the unique effect(s) of mentor support and underrepresented status on belonging at wave 2 over and above sense of belonging at wave 1.

Our regression equation follows:

$$\begin{aligned}\text{Belonging}_{w2} = {} & \beta_0 + \beta_1 \times \text{Belonging}_{w1} \\ & + \beta_2 \times \text{Mentor Support}_{w1} \\ & + \beta_3 \times \text{Underrepresented Status} \\ & + \beta_4 \times \text{Mentor Support}_{w1} \times \text{Underrepresented Status}\end{aligned} \quad (1)$$

Given the interaction term in the model, the coefficients for mentor support and underrepresented status reflect the effect of each variable for cases where mentor support and underrepresented status are coded as zero [1]. That is, the output for our regression is conditional and in order to extract theoretically meaningful effects from the model results, we discuss the conditional effects of our model instead of presenting the regression output (for more information on conditional effects, see [1, 5, 9, 21]). The coefficient for the interaction term (β_4) in our model did not reach the conventional level of statistical significance ($p \leq .05$), β = .13, SE = .07, p = .06. Nonetheless, we examined our a priori hypothesis that the effect of mentor support on sense of belonging would differ

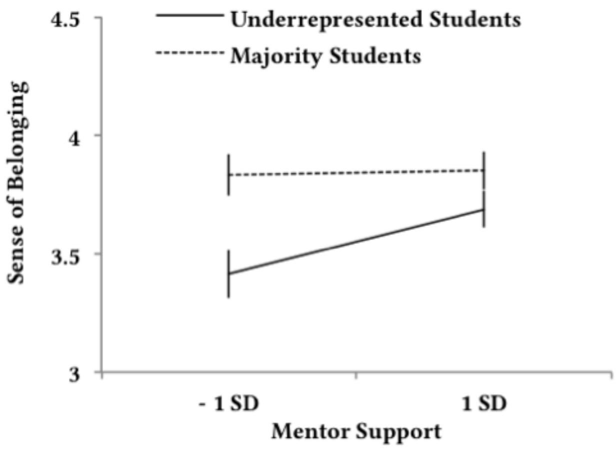

Figure 1: Effect of mentor support on belonging by underrepresented status.
Note. Slopes represent the relationship between mentor support and sense of belonging for underrepresented versus majority students. 95% confidence intervals are presented at the end of each line. SD = standard deviation below (-1) and above (1) the mean for mentor support.

for underrepresented versus majority students[7]. To do so, we first calculated the simple slopes for underrepresented versus majority students: the slope for the relationship between mentor support and sense of belonging was positive and significant for underrepresented students, β = .14, SE = .06, $p \leq .01$ (see solid black line in Figure 1), but was not significant for majority students, β = .01, SE = .05, p = .85 (see dashed black line in Figure 1).

We also assessed underrepresented versus majority students' sense of belonging at wave 2 at different levels of mentor support. We did this by re-running our original regression model using two new iterations: one centering mentor support at 1 SD below the mean for mentor support and a second centering mentor support 1 SD above the mean for mentor support (see [1, 21]). Here, we found underrepresented students reported a significantly lower sense of belonging than majority students when mentor support was low, β = -.42, SE = .14, $p \leq .01$ (see the gap in sense of belonging for the two groups at -1SD below the mean for mentor support in Figure 1). But, when mentor support was high, there was no significant difference in underrepresented versus majority students' sense of belonging, β = -.16, SE = .12, p = .16 (see narrow, nonsignificant difference in sense of belonging at 1 SD above the mean for mentor support in Figure 1). Thus, a strong sense of mentor support eliminated the gap in sense of belonging among underrepresented versus majority students.

4 DISCUSSION

The current study investigated the long-term impact of early formal research experiences on computing students' sense of mentor support and belonging. Our results indicate early formal research fosters a strong sense of mentor support among students. A sense of mentor support, in turn, predicted a stronger sense of belonging among underrepresented students but not majority students. In fact, the typical gap in sense of belonging among underrepresented and majority students [8, 15] disappeared among students with a strong sense of mentor support (see Figure 1). Given that a secure sense of belonging is an important predictor of academic motivation and persistence [10, 11, 30, 31], our findings suggest early formal research may be one way to help retain lower division underrepresented students in computing.

4.1 Limitations and future research

A limitation of the current work is that we treated women of all race/ethnic background and men from underrepresented backgrounds as a single demographic group. The same can be said for Asian and White men. These higher order groups were necessary to conduct reliable statistical analyses, but they did not account for unique experiences of students from different racial/ethnic groups. Future studies on formal research should attend to specific student group's experiences.

Another limitation to the current work is our broad focus on formal research. That is, formal research comes in many shapes and sizes (e.g., during the summer versus school year; independent study versus group work). Future research should gauge the most impactful type of formal research for lower division students, and whether students' sense of mentor support varies as a function of formal research characteristics.

4.2 Recommendation: Expose students to research early in college

Based on the current research findings, we recommend computing departments engage lower division students with formal research. In what follows, we describe one formal research program for lower division students at the University of California, San Diego (UCSD) called the Computer Science and Engineering Early Research Scholars Program (ERSP). The creator of this program is Christine Alvarado (a co-author on this paper). We encourage readers to visit the program's website at ersp.ucsd.edu, read a recent paper about the ERSP [4], and contact her directly with inquiries.

4.3 An example: ERSP

The ERSP engages second-year computer science and engineering students in team-based research apprentice experiences over a single academic year. The program wa designed to target and support lower division underrepresented students who do not typically have the same level of experience or confidence as their majority group peers. The program uses several techniques to engage and support students. For one, all projects are group-based: upon entry into the program, students are grouped into teams of four and matched with a research mentor. Second, the program provides a research methods course that teaches technical skills, independent learning skills, and collaboration skills. Finally, the program uses a dual-mentoring model to ensure students are well supported without placing undue burden on the research mentors. While a research mentor provides

[7]See [32] for the American Statistical AssociationâĂŹs recent discussion on why scientists ought not rely solely on whether a p value exceeds an arbitrary threshold. See also [22].

technical support and problem solving specific to the project, a separate centralized ERSP mentoring team provides general mentoring in goal setting, technical communication, teamwork, and question framing.

This program began in 2013 and has undergone thorough evaluation to understand when and why the program is effective for students [28, 29]. For instance, external evaluators have found that the program is most effective when research projects are calibrated to the level of students' skillset; morale suffers when projects are too challenging for students. Further, when students' research groups collaborate well, they also show more interest in pursuing a research career later on. In addition to benefits for the students, ERSP at UCSD has helped build a culture and practice of early undergraduate research, particularly for students from groups that are underrepresented in computer science.

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APPENDIX

Table 1: Longitudinal Design

Longitudinal time point	When survey occurred	What was asked
Wave 1	Second year in college	- Participated in formal research during the past year (Yes/No) - Current sense of mentor support - Current sense of belonging
Wave 2	Third year in college	- Current sense of belonging

Note. Wave 1 = initial survey. Wave 2 = follow up survey.

Table 2: Matched Sample Demographics

		Asian/ Asian American		Black/ African American		Hispanic/ Latina/o		White/ Caucasian		Mixed Minority		Mixed Majority		Other	
		W	M	W	M	W	M	W	M	W	M	W	M	W	M
FR n=110	U	14%		0%	2%	1%	5%	14%		4%	4%	4%		3%	1%
	Maj		15%						31%				2%		
No FR n=110	U	15%		3%	2%	1%	6%	11%		3%	5%	1%		1%	3%
	Maj		12%						36%				1%		

Note. FR = formal research experiences. U = underrepresented. Maj = Majority. W = women. M = men. Mixed Minority = students from more than one ethnic group, at least one of which is Black/African American or Hispanic/Latina/o. Mixed Majority = students who are Asian and White. Other = students who identify with one or more ethnic group not listed. % = percent of a group within FR/No FR (e.g., 14% of FR group is Asian/Asian American women).

Table 3: Survey Questions

Variables, Questions, and Response Options
Formal research question
Since September [2014 for cohort 1, 2015 for cohort 2], have you participated in any "formal" research experiences? Formal research includes an experience you applied for, and through which you worked closely with a mentor or research advisor. Yes/No
Mentor support
To what extend to you have a mentor who ... -helps you improve your computing skills? -shows compassion for any concerns and feelings you discussed with them? -shares personal experiences as an alternative perspective to your problems? -explores career options with you? (1) Not at all, (2) A little, (3) Somewhat, (4) Quite a bit, (5) Very much
Sense of belonging
I feel like I belong in computing. I feel like an outsider in the computing community (reverse-coded). I feel welcomed in the computing community. (1) Strongly disagree, (2) Somewhat disagree, (3) Neither agree nor disagree, (4) Somewhat agree, (5) Strongly agree