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Advancing Gender Equity and Sense of Belonging in Computing: Are Documented Best Practices Representative of Upward Transfer Students?

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ABSTRACT

Supporting upward transfer students is critical to diversifying STEM. This study provides insight into how we can best support upward transfer students in computing, one of the least diverse STEM disciplines. Specifically, we expand upon recent research on sense of belonging to examine how the predictors of belonging might be unique for upward transfer students, focusing closely on upward transfer women's experiences. Findings highlight three unique predictors of sense of belonging for upward transfer students beyond those documented in prior research on students in the aggregate. Other college experiences – like feeling supported by computing peers – positively predicted belonging for all students, but were not equitably available to upward transfer students, with upward transfer women reporting the lowest levels of peer support compared to all other groups.

Despite being the majority of undergraduate students across disciplines, women make up only 18% of bachelor's degree recipients in computing (National Center for Education Statistics [NCES], 2019). This persistent gender gap is particularly troubling considering the financial reward and status associated with earning a computing degree (Bureau of Labor Statistics, 2016). Researchers have argued that one reason for the lack of progress in diversifying computing is due to the fact that research on gender equity in computing programs tends to focus on a relatively privileged subset of students from underrepresented groups (e.g., white women from high-income backgrounds with college-educated parents; Blaney & Stout, 2017; Sax et al., 2018). The present study addresses this limitation of the literature by focusing on one specific group that is key to diversifying STEM fields: upward transfer students.

Upward transfer (i.e., the process of transferring from a two-year college to a four-year institution) is a major function of community colleges (Cohen & Brawer, 2008), and upward transfer students have been identified as a critical group within efforts to diversity STEM (see Bahr et al., 2017). Relative to computing majors who follow *traditional* pathways from high school to four-year institutions, upward transfer students tend to be more diverse in terms of race/ethnicity, family composition, socio-economic status, and other key factors (Blaney, 2020a; Hawthorne, 2015; Kahlon et al., 2018; Lyon & Denner, 2017). Further, community colleges serve as a key entry point to STEM and other four-year degree programs for women from minoritized racial/ethnic groups and those from low-income backgrounds (Mullin, 2012; Starobin & Laanan, 2010; Wang & Wickersham, 2019). As such, broadening access to upward transfer pathways in computing is critical to diversifying the field.

As a first step in understanding upward transfer students' success in computing, this study focuses on sense of belonging, which refers to one's sense that they fit in and are a valued member of a given community (Goodenow, 1993). While very little is known about upward transfer computing students,

broader scholarship on equity in computing emphasizes the importance of sense of belonging (e.g., Blaney & Stout, 2017; Master et al., 2016; Stout & Blaney, 2017). Researchers posit that developing sense of belonging among minoritized groups in computing is critical, and studies have consistently documented the important role belonging plays in retaining women in STEM (Espinosa, 2011; Freeman et al., 2007; Pittman & Richmond, 2008). Particularly relevant to the present work, Sax et al. (2018) recently applied Strayhorn's (2012) model of sense of belonging to a computing context, examining ways in which the predictors of sense of belonging differ by gender. In doing so, the authors point to best practices for supporting and fostering belonging among women in undergraduate computing courses. Yet, more research is needed to determine the extent to which these and other studies are representative of specific groups (e.g., upward transfer women).

The present study seeks to replicate and build upon Sax et al.'s (2018) recent study of belonging by examining how sense of belonging might uniquely develop for upward transfer computing students. Additionally, we focus on the intersection of upward transfer status and gender to center the experiences of upward transfer women. In doing so, this study provides insight into the extent to which documented best practices for supporting women in computing may or may not be applicable to upward transfer students. The following questions frame this inquiry:

(1) How does sense of belonging among computing students change over time, and does this differ by upward transfer status and gender?
(2) What factors predict belonging among computing students, and how does this differ by upward transfer status?
(3) How does exposure to predictors of belonging differ by upward transfer status and gender?

Literature review and conceptual framework

The present study is guided by literature on gender and equity in undergraduate computing, including studies that more specifically focus on women's sense of belonging in computing contexts. To provide a frame for this study, we merge this literature with recent studies of upward transfer pathways, which increasingly consider the unique experiences of upward transfer students in STEM.

Gender equity and sense of belonging in STEM

The gender gap in undergraduate computing participation has widened in recent decades, with women today representing only 18% of bachelor's degree recipients in computing (NCES, 2019), despite being over 40% of new computer science undergraduates in the 1980s (Sax et al., 2017). Further, among the women who do pursue computing degrees at the undergraduate level, access may be particularly limited for women who occupy other underrepresented and/or minoritized identities in computing (Rodriguez & Lehman, 2017). Because of these persistent and growing inequities, researchers have spent decades exploring the factors that predict women's decision to enroll in computing courses (e.g., Varma, 2010), pursue a computing degree (e.g., Margolis & Fisher, 2002; Sax et al., 2017), and persist and succeed in computing majors and careers (Burke et al., 2006; Misa, 2011).

Sense of belonging has become an increasing focus within research on women and gender equity in computing contexts (e.g., Blaney & Stout, 2017; Cheryan et al., 2009; Sax et al., 2018). In their systemic literature review on the underrepresentation of women and girls in computing at different life stages, Main and Schimpf (2017) found that sense of belonging has frequently been studied in relation to women's initial decision to pursue a computing major and their retention in computing careers. At the undergraduate level specifically, related studies have been guided by Strayhorn's (2012) work on sense of belonging in college. Strayhorn's (2012) sense of belonging model argues that belonging can take on heightened importance for marginalized and underrepresented groups (e.g., women in computing), and that it can change over time as a product of college experiences. Sax et al. (2018) applied

Strayhorn's (2012) model to focus on belonging among computing students, paying particular attention to how sense of belonging develops for women and students from underrepresented and minoritized racial/ethnic groups in computing courses. Together, this literature has identified the important role of incoming orientations, family and contextual factors, and college experiences in shaping belonging outcomes, which we review below.

Incoming orientations and precollege experiences

Strayhorn's (2012) model describes how incoming orientations shape the ways in which college students develop their sense of belonging. Indeed, incoming values (e.g., valuing a career where one can have a social impact) and orientations (e.g., artistic and creative orientations) have been shown to predict sense of belonging among computing undergraduates, with certain incoming orientations appearing to play a more significant role in shaping belonging outcomes for women than for men (Sax et al., 2018). More broadly, incoming values and orientations may impact women's initial and continued decision to pursue computing (Beyer, 2014; Sax et al., 2017).

Family and contextual factors

Family characteristics have also been shown to predict key outcomes for computing undergraduates, particularly women. Relative to all other groups, first-generation college women have been shown to report lower sense of belonging in computing when they arrive at college (Blaney & Stout, 2017), suggesting that parental education and gender may collectively shape college computing outcomes. This speaks to the importance of understanding the unique experiences of upward transfer students in STEM, who may be more likely to be first-generation college students, relative to students who follow more traditional pathways from high school to college (Blaney, 2020a).

In addition to parental education level, ongoing family support and experiences may influence the way sense of belonging develops during college. Parents and other family members determine students' precollege exposure to computers, which may shape their initial interest in pursuing computer science (Margolis & Fisher, 2002; Margolis et al., 2000), and their sense of belonging in computing (Sax et al., 2018). More broadly, family support and encouragement in one's degree pursuits is important for all computing students (Tillberg & Cohoon, 2005), and some studies show that family support plays a particularly important role for women in STEM who follow community college pathways (Packard et al., 2011).

Beyond family, other contextual factors may impact sense of belonging in STEM. Exposure to the larger computing field has been explored in prior studies of gender and women's success and belonging in undergraduate computing (e.g., Blaney, forthcoming; G. C. Townsend & Sloan, 2016). More specifically, attending at least one diversity-related computing conference (e.g., the Grace Hopper Celebration of Women in Computing) positively predicts women's confidence in their ability to become a leader in computing (Blaney, 2020b). Further, non-college contextual factors may play a larger role for upward transfer students who are more likely to be working their way through college (Blaney, 2020a) and balancing myriad life demands on top of pursuing a STEM degree (Wickersham & Wang, 2016).

College environments

Strayhorn also highlights how inequities in sense of belonging are perpetuated within college environments. Relevant to the present work, prior research documents the prevailing and unnecessarily masculine culture that permeates computing programs (Ensmenger, 2010). While hostile environments may lead to weaker feelings of belonging for women in computing, other studies show that instructor's use of inclusive pedagogies is positively associated with belonging outcomes, and that this association is strongest for first-generation college women in computing (Blaney & Stout, 2017). Sax et al. (2018) also found that support from computing students and the computing department positively predict sense of belonging for women and men alike. Further, supportive interactions with peers may promote women's persistence in computing (Varma, 2010). Other research applying

Strayhorn's model of belonging within a STEM context identifies the importance of identity-based groups for fostering STEM sense of belonging, particularly for Latina students (Rodriguez & Blaney, 2020). Such groups may serve as counter spaces, which can be critically important for retaining women in STEM (Ong et al., 2018). Other studies have considered more specific departmental procedures, revealing that exclusionary practices like competitive enrollment policies negatively predict sense of belonging for all students (Nguyen & Lewis, 2020); we might also expect that such practices could be especially detrimental for upward transfer students who are already navigating complex prerequisite and transfer policies (discussed below).

Upward transfer pathways

The present study is also guided by literature on upward transfer students. When exploring upward transfer student experiences, it is important to acknowledge that transferring from a two- to four-year institution is a complex process, comprised of many barriers (Monaghan & Attewell, 2015). As such, the students who successfully navigate upward transfer represent a self-selected, talented, and ambitious group of students. Laanan et al. (2010) popularized the term "transfer student capital" to describe this, referring to the expertise that students bring with them to their receiving institutions (p. 177). Transfer capital includes the knowledge students gain from navigating the intricacies of credit transfer agreements between institutions, course and program prerequisites, and accessing each institution's financial aid and advising resources. Transfer capital may play a particularly important role for students pursuing majors like computing and engineering, which are often characterized by having inaccessible, competitive, and inflexible prerequisite requirements that create additional barriers for would-be majors (Bennedsen & Caspersen, 2007; Suresh, 2006). Broadly, literature on transfer student capital provides context for existing research on post-transfer outcomes, requiring us to continually ask ourselves who is represented in studies of post-transfer success and – perhaps more importantly – who is not.

In addition to the characteristics that students bring with them to receiving institutions, other studies explore post-transfer involvement and engagement (see Bahr et al., 2013). For example, involvement in student clubs, interactions with faculty, and engagement with peers have been shown to predict retention and academic success among upward transfer students (B. K. Townsend & Wilson, 2009; Wang, 2009). Similarly, researchers have documented the important role receiving universities play in orienting and engaging community college transfer students (B. K. Townsend & Wilson, 2006). In particular, this literature highlights the important role four-year institutions must play in fostering belonging and success among transfer students by creating an inclusive institutional culture (e.g., Jain et al., 2016; Laanan et al., 2010). Unfortunately, faculty at receiving institutions may be unaware of transfer student processes and hold negative perceptions of upward transfers (Hyatt & Smith, 2020), possibly leading to lower sense of belonging among upward transfer students.

Upward transfer in STEM
Scholars have recently been bridging the gap between research on equity in STEM and that of upward transfer success, focusing specifically on upward transfer pathways in STEM fields (see Wang, 2016). Somewhat consistent with the broader literature, this research documents the importance of contextual factors, classroom experiences, support from faculty, and specific transfer programming like transfer orientations and mentoring programs (Jackson & Laanan, 2011; Packard et al., 2011; Starobin et al., 2016; Wang, 2016). Increasingly, this literature has explored the experiences of women in STEM (e.g., Wickersham & Wang, 2016), recognizing the critical role community college pathways play in increasing women's access to four-year STEM degrees. This research broadly documents the unique experiences of upward transfer women, who are often required to juggle employment and family responsibilities alongside complex transfer processes and hostility toward women in STEM (Wickersham & Wang, 2016).

While a growing body of literature has explored upward transfer pathways in STEM fields, upward transfer students have been largely neglected in studies of equity in computing until very recently (Kahlon et al., 2019). Emerging research on this topic reveals that upward transfer students tend to be more diverse than other computing students (Blaney, 2020a). However, upward transfer computing students also report lower peer support, lower levels of mentorship, and less support from computing departments than their peers, suggesting that more research is needed on how to best support this diverse group of computing students (Blaney, 2020a). This same study also provides insight into gender inequity in access to upward transfer computing pathways; specifically, women in the study represented just 22% of upward transfer computing majors, relative to 27% of majors who followed more traditional pathways (Blaney, 2020a). More research is needed to understand why upward transfer women are so underrepresented in computing and how to support this group.

Methods

Our study serves as a partial replication and extension of Sax et al.'s (2018) application of Strayhorn's (2012) model of sense of belonging. To that end, we utilized existing data from the BRAID Research Project, which surveys computing students from 15 research universities across the United States, including two private and 13 public institutions.[1] Computing programs at the participating institutions largely mirror national trends, with women being underrepresented across all campuses. Two of the participating institutions are federally designated as Hispanic-Serving, while the remaining 13 represent predominantly white institutions.

In terms of the specific survey sample, we relied on data from $N = 1,829$ students who enrolled in an introductory-level computing course during the 2016–2017 academic year and completed a pre- and post-test survey at the beginning and end of their course. To incentivize survey response, the first 400 respondents of each survey received an Amazon gift card. Among students in the sample, 4.6% were upward transfer women, 11.8% were upward transfer men, 30.7% were non-upward transfer women, and 52.9% were non-upward transfer men. The majority of respondents were from white (45.4%) or Asian (27.1%) racial/ethnic groups. Eleven percent were from Latina/o/x groups, 4.9% were Black/ African American, 0.3% were from Native/Indigenous groups, and 10.8% identified with two or more racial/ethnic groups on the survey. Additionally, half of the respondents were computing majors; to account for this variation in the sample, we included major as a covariate in regression analyses.

Measures

With some exceptions, variables were selected to mirror those used by Sax et al. (2018). We describe this process below, focusing on detailed descriptions for variables that were significant in the present study. Means and standard deviations for all significant variables are included in the Appendix, Table A1. All composite measures are described in Table A2.

Dependent variable

To measure belonging, we relied on Sax et al.'s (2018) measure of sense of belonging in the field of computing. Specifically, students indicated their agreement with the following statements on a five-point scale: I feel like I belong in computing; I do not have much in common with other computing students (reverse-coded); I feel welcomed in the computing community. Items were summed to create a measure ranging from 3 (low belonging) to 15 (high belonging). This composite measure had a Cronbach's alpha of 0.76, indicating reliability.

Independent variables

Background variables first included a direct pretest of sense of belonging at the beginning of the course (see Table A2). Students also self-reported whether or not they had transferred from a community college on the survey (0 = non-upward transfer; 1 = upward transfer). Additionally, we included

a control measure for whether or not students were computing majors at the beginning of the computing course (0 = non-computing major; 1 = computing major), which was treated as a covariate. In keeping with the original belonging study, background variables also included a dichotomous measure of gender (0 = man; 1 = woman) and whether or not students identified with one or more underrepresented racially minoritized (URM) groups (0 = majority racial/ethnic identity; 1 = URM racial/ethnic identity). To create the URM status variable, white and Asian/Asian American students were counted as the majority group; students from Black/African American, Latina/o/x, and Native/ Indigenous groups were coded as URM. Next, to measure parent career, students indicated the career field of each parent as computing, another STEM field, or something else; responses were used to create a dichotomous measure of whether or not students had at least one parent with a computing career (0 = non-computing career; 1 = computing career). We also included measures of parent education level (1 = high school or less; 2 = some college or associate's degree; 3 = bachelor's degree; 4 = graduate/professional degree) and socioeconomic status, which was measured using students' self-reports on a five-point scale ranging from 1 = poor to 5 = wealthy.

We controlled for prior academic achievement by examining students' average high school grade on a 9-point scale ranging from 1 = D to 9 = A/A + . Next, we included prior programming experience, which was measured by creating a scale summing seven items where students indicated whether or not they had specific types of prior programming experiences (e.g., took a computer programming course online). Finally, background characteristics encompass students' incoming orientations, captured by incoming social, leadership, artistic, family, and scholarly orientations, each of which were measured by composite variables (see Table A2).

College experience variables largely focused on computing departments and classrooms. First, we included two composite variables capturing support from the computing department and support from other computing students, each described in Table A2. Next, we included measures of students' experiences in computing classrooms, which were measured through students' self-reports of how frequently their computing instructors used lecture and discussion, each measured on a five-point scale (1 = never; 5 = always). Additionally, we included composite measures capturing students' exposure to broader types of pedagogical practices (i.e., collaborative pedagogies, use of relevant course content, instructor inclusivity, and frequency of student–instructor interactions; see Table A2).

Student behaviors were also included to capture students' college experiences. To assess this, we used single-item measures of how many hours per week students spent (on average) on the following activities: socializing, playing video games, participating in computing-related student groups, participating in non-computing student groups, studying, and using online social networking sites. For all items, students responded on an 8-point scaling ranging from 1 = no hours to 8 = over 20 hours. Importantly, time spent socializing and time spent in non-computing student groups were not included in the original Sax et al. (2018) study; we included these two variables to be more comprehensive in capturing how students spent their time. The other four student behavior variables (time spent using video games, using social networking sites, studying, and in computing student groups) were included in the original study.

Analytical procedures

We used general linear modeling (GLM) to examine how change in belonging over time might differ as a product of upward transfer status and gender (Research Question One). Next, we used regression analysis, organizing variables in accordance with Sax et al.'s (2018) belonging study, followed by tests of interaction terms to examine whether the predictors of belonging might differ by upward transfer status (Research Question Two). Before creating the final regression model, we ran two exploratory models, separating students by upward transfer status. Variables that were significant in either of the two exploratory models were then entered into the final model shown in Table 1; this was done to ensure that predictors that may be unique to upward transfer students were captured, recognizing that unique predictors could otherwise be masked by the overrepresentation of non-transfer students. Due

to sample size limitations, we were not able to examine whether predictors might also differ by gender (a large focus of the original Sax et al. [2018] study); however, we did run independent samples t-tests and ANOVAs to examine how *exposure* to significant predictors of sense of belonging might differ by upward transfer status, gender, or both (Research Question Three).

Findings

Belonging changes over time

Research Question One asks about how sense of belonging changes over time, and how these changes might differ by upward transfer status and gender. Before examining how change might vary for these different groups, a paired sample t-test showed that, among students in the aggregate, sense of belonging did not change significantly over time, $t(1720) = 1.17$; $p = .242$. However, this pattern differed by gender ($F = 9.50$; $p = .002$); specifically, while men's sense of belonging in computing remained relatively stable over time, women's sense of belonging on the posttest ($M = 9.09$, $SD = 2.82$) was lower than their belonging at the beginning of the course ($M = 9.33$; $SD = 2.65$).[2] Changes in sense of belonging over time did not differ significantly by upward transfer status ($F = 0.01$; $p = .923$) or the intersection upward transfer and gender ($F = 2.52$; $p = .112$).

Though changes over time were mostly non-significant – with the exception of women's declining belonging scores – patterns for all groups are illustrated in Figure 1. As shown in the figure, while men who did not transfer from a community college (i.e., the majority of the sample) began the course with the highest belonging scores and remained stable in their scores over time, this was not true of other groups. Upward transfer men started their computing course with lower belonging scores than other men in the sample, but saw modest non-significant increases over time, such that they left the course with scores identical to those of other men. However, the lack of significance makes it difficult to infer meaning from these patterns.

In contrast to men, all women, regardless of upward transfer status, began the computing course with lower belonging than their male counterparts *and* had decreasing belonging scores over time.[3] These patterns of inequity are somewhat unsurprising. Significant gender gaps in both incoming scores and change over time mirror the original Sax et al. (2018) study. Further, given the sexism documented within computing majors (e.g., Michell et al., 2018), we might expect that gender stratification would increase as students have greater exposure to these sexist college environments. However, it is interesting that similar patterns did not emerge by upward transfer status; perhaps, within gendered computing environments, gender is more salient than upward transfer status.

Predictors of belonging for all students

The regression model predicting sense of belonging was developed in three steps and is shown in Table 1. The final model explained approximately 64% of the variance in the dependent variable ($R^2 = 0.64$). The

Table 1. Predictors of sense of belonging in computing.

	Step 1: Background Variables		Step 2: Department Experiences		Step 3: Student Behaviors	
	ß	Sig.	ß	Sig.	ß	Sig.
BACKGROUND VARIABLES						
Pretest	0.666	***	0.564	***	0.548	***
Upward Transfer	−0.005		0.009		0.003	
Gender (W)	−0.117	***	−0.121	***	−0.098	***
URM Status	−0.026		−0.023		−0.020	
Incoming Computing Major	0.062	**	0.043	*	0.038	*
Parent Career (Computing)	0.012		0.016		0.019	
Programming Experience	0.071	***	0.076	***	0.076	***
DEPARTMENT EXPERIENCES						

(Continued)

Table 1. (Continued).

	Step 1: Background Variables		Step 2: Department Experiences		Step 3: Student Behaviors	
	ß	Sig.	ß	Sig.	ß	Sig.
Collaborative Pedagogies			−0.033	*	−0.030	
Department Support			0.209	***	0.204	***
Peer Support			0.091	***	0.094	***
STUDENT BEHAVIORS						
HPW Non-computing Groups					−0.041	*
HPW Video Games					0.055	**
HPW Social Networking					−0.039	*
HPW Socializing					0.017	

$*p < .05$; $**p < .01$; $*** p < .001$. UT = Upward Transfer. HPW = Hours Per Week. Variables were entered into the model in three steps. In Step 1, background variables were entered alone, department experience variables were added in Step 2, and all variables (including student behaviors) were added to the model in Step 3.
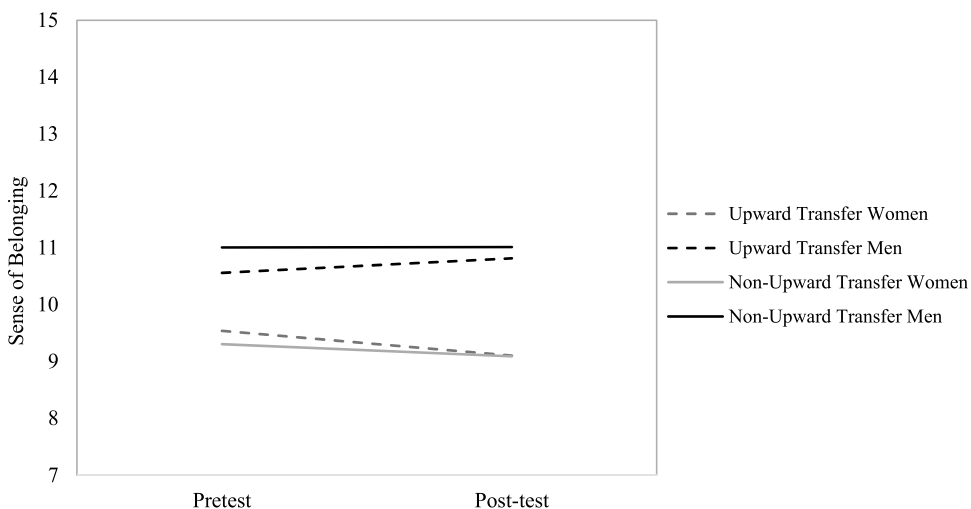

Figure 1. Change in sense of belonging by gender and upward transfer status.

vast majority of the variance (58%) was explained by the characteristics that students brought with them to the computing course, though several significant variables related to college experiences also emerged. Below, we discuss all significant predictors, focusing on background characteristics and then college experience variables, which we break into department experiences and individual student behaviors.

Background characteristics

Unsurprisingly, incoming sense of belonging was the strongest predictor of sense of belonging at the end of the term. Consistent with the results above, while upward transfer status was not significant, gender was a significant predictor at every step of the model. That is, even after controlling for all other variables, women had lower sense of belonging than men in the sample, which is consistent with Sax et al.'s (2018) findings. Also consistent with the Sax et al. study, having more prior exposure to programming positively predicted sense of belonging.

College experiences

While background characteristics explained the majority of the variance in the model, significant predictors related to college experiences point to specific implications for faculty and other professionals seeking to enhance computing students' sense of belonging. College experience variables were organized into characteristics of computing programs (Step 2) and student behaviors (Step 3), with characteristics of the program generally playing a larger role than student behaviors (i.e., experiences in the computing department and computing classes explained an additional 5% of the variance in the dependent variable, while student behaviors explained only 0.5% of additional variance in belonging outcomes).[4] More specifically, after the pretest, feeling generally supported by the computing department was the strongest positive predictor of sense of belonging in computing. Similarly, being supported by other computing students was associated with greater feelings of belonging at the end of the course. Counterintuitively, having greater exposure to collaborative pedagogies (e.g., group assignments) within computing classrooms was a negative predictor of sense of belonging when it entered the model at Step 2, but it was non-significant in the final model.

Student behaviors were entered last, revealing three additional significant predictors. Hours spent each week playing video games was a positive predictor of sense of belonging (i.e., students who spent more time playing video games had higher sense of belonging), while more time spent each week on social networking sites was a negative predictor (i.e., students who spent time using social networking sites had lower sense of belonging). Finally, and somewhat counterintuitively, hours per week spent in non-computing student groups was a modest negative predictor of belonging, suggesting that when students engage in non-computing activities on college campuses, they may have decreasing feelings of belonging to their discipline.

Unique predictors for upward transfer students

The second half of Research Question Two asks about how predictors of sense of belonging might differ by upward transfer student status, which we examined by testing for interaction effects. These tests revealed three interaction effects, significantly contributing to the variance explained by the model (R^2 change = 0.005). First, and as shown in Figure 2, we found a significant interaction ($B = -0.96$; $SE = 0.35$, $p = .006$), such that having a parent with a computing career was a positive predictor of belonging for non-transfers but a negative predictor for upward transfer students. Other findings suggest that upward transfer students may uniquely benefit from frequent social interactions ($B = 0.31$; $SE = 0.14$, $p = .022$). More specifically, we found that spending more hours each week
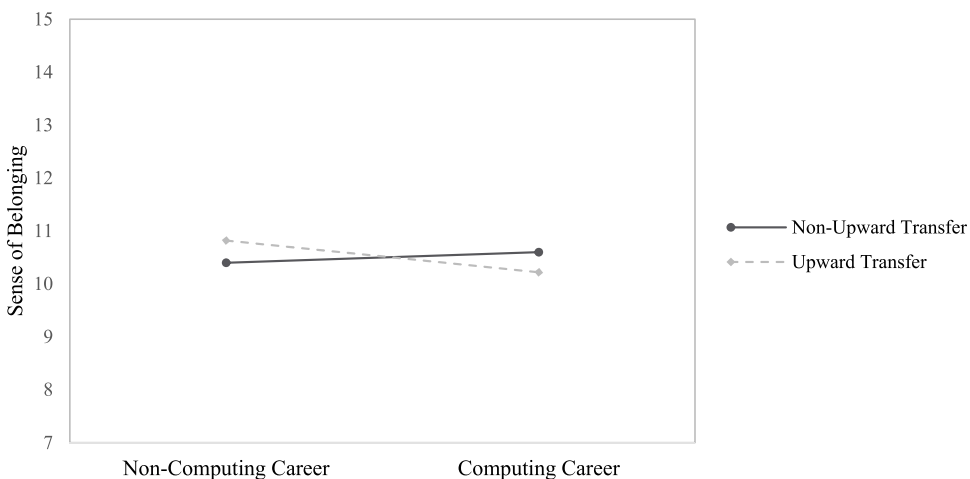

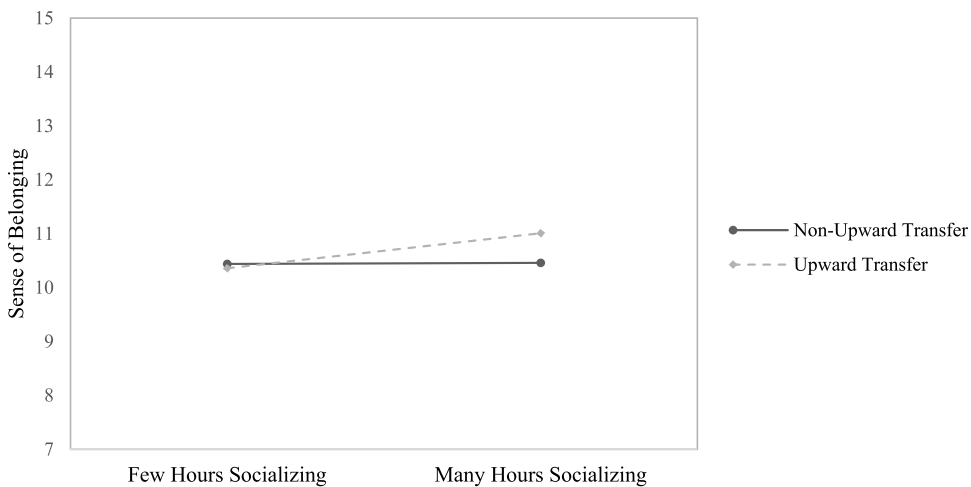**Figure 2.** Conditional effect of parent computing career.

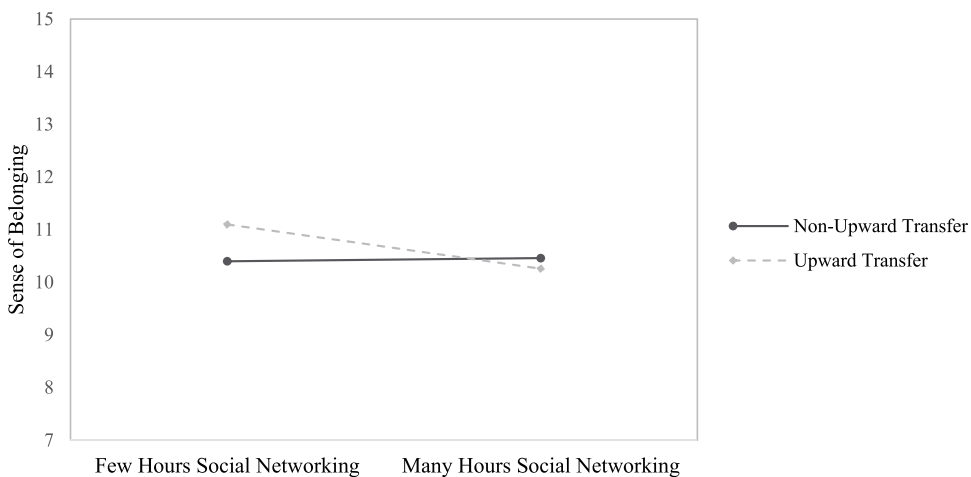**Figure 3.** Conditional effect of time spent socializing.

Figure 4. Conditional effect of time spent using social networking websites.

socializing with friends positively predicted sense of belonging for upward transfer students but was a non-significant predictor for other students in the sample (see Figure 3). Finally, the third significant interaction effect ($B = -0.43$; $SE = 0.14$, $p = .001$) reveals that, among upward transfer students only, spending time on social networking sites negatively predicted sense of belonging in computing (see Figure 4).

Exposure to key predictors of belonging differs by upward transfer status and gender

While sample size limitations restricted our ability to account for gender and upward transfer status together in regression analyses, our final research question (Research Question Three) focuses on how *exposure* to significant predictors might differ by gender and upward transfer status. We focused these analyses on significant college experience variables and prior programming experience, as these are variables that are within the control of colleges and universities (i.e., prior programming experience may reflect experiences at community colleges or bridge programs, and college experience variables

Table 2. Mean differences on key belonging predictors, by gender and upward transfer status separately.

	Mean (SD)					
	By UT Status			By Gender		
	Non-Transfer	Upward Transfer	Sig.	Men	Women	Sig.
Programming Experience	1.15 (1.07)	1.44 (1.19)	***	1.29 (1.12)	0.99 (1.02)	***
Collaborative Pedagogies	7.46 (3.26)	6.89 (3.17)	**	7.45 (3.18)	7.23 (3.39)	
Department Support	14.19 (3.16)	14.08 (3.31)		14.38 (3.14)	13.80 (3.22)	***
Peer Support	12.77 (4.39)	11.13 (4.57)	***	12.73 (4.41)	12.08 (4.50)	***
HPW Non-computing Groups	3.08 (1.82)	2.51 (1.83)	***	2.90 (1.85)	3.17 1.79)	***
HPW Video Games	3.09 (1.89)	3.12 (2.11)		3.57 (1.91)	2.17 (1.60)	***
HPW Social Networking	3.59 (1.61)	3.40 (1.77)	*	3.40 (1.65)	3.87 (1.55)	***
HPW Socializing	4.55 (1.62)	3.97 (1.77)	***	4.48 (1.68)	4.43 (1.60)	

$*p < .05$; $**p < .01$; $*** p < .001$. UT = Upward Transfer. HPW = Hours per Week.

Table 3. Mean differences on key belonging predictors, by gender and upward transfer status together.

	Mean			
	UT Women (a)	UT Men (b)	Non-UT Women (c)	Non-UT Men (d)
Programming Experience	1.30$_b$	1.48$_{acd}$	0.97$_{bd}$	1.26$_{bc}$
Collaborative Pedagogies	6.94	6.91$_d$	7.25	7.59$_b$
Department Support	14.11	14.01	13.75$_d$	14.50$_c$
Peer Support	10.80$_{cd}$	11.33$_{cd}$	12.32$_{abd}$	13.02$_{abc}$
HPW Non-computing Groups	2.42$_{cd}$	2.39$_{cd}$	3.25$_{abd}$	2.96$_{abc}$
HPW Video Games	2.44$_{bd}$	3.52$_{ac}$	2.24$_{bd}$	3.63$_{ac}$
HPW Social Networking	3.78	3.26$_c$	3.87$_{bd}$	3.46$_c$
HPW Socializing	3.98$_{cd}$	3.96$_{cd}$	4.53$_{ab}$	4.60$_{ab}$

Subscripts indicate significant differences at $p < .05$. UT = Upward Transfer. HPW = Hours per Week.

would reflect factors that could be addressed by computing departments both at community colleges and receiving institutions). More specifically, we first ran independent samples t-tests on all of these variables to examine differences by upward transfer status and gender separately. As shown in Table 2, these analyses revealed that students' exposure to the majority of significant independent variables differed by upward transfer status and/or gender.

Notably, upward transfer students reported more prior programming experience than non-transfer students, which is unsurprising, as these students may have been exposed to programming courses or activities at their two-year colleges. Perhaps the fact that upward transfer students have more prior experience in computing may explain why gaps in sense of belonging did not emerge by upward transfer status. That is, upward transfer students' greater exposure to computing may buffer against transfer stigma at receiving institutions (see Shaw et al., 2019). Upward transfers also reported lower scores on collaborative pedagogies, an inconsistently negative predictor of belonging in our study. At the same time, upward transfer students reported lower scores on peer support and indicated that they spent less time in non-computing student groups, using social networking sites, and socializing with peers. The lack of peer support reported by upward transfer students is consistent with prior literature (e.g., Blaney, 2020a) and is particularly concerning, given that peer support was a consistently positive predictor of belonging in the present study, as well as the Sax et al. (2018) study of belonging.

With the exception of time spent socializing and exposure to collaborative pedagogies in computing courses, every predictor variable differed by gender. On average, women reported less prior exposure to programming, less support from their department and peers in computing, more time spent in non-computing student groups and using social networking sites, and less time playing video games. That is, gender gaps tended to reveal that women had lower exposure to positive predictors of belonging (e.g., departmental support) and greater exposure to negative predictors of belonging (e.g., time spent in non-computing groups), which may partially explain persistent gender gaps in sense of belonging documented here and in prior literature.

Finally, we ran a series of ANOVAs to examine how key predictors of belonging might differ by gender and upward transfer status together (see Table 3). Beyond the gender differences shown in Table 2, these analyses reveal that upward transfer men had more prior programming experience than all other groups, which may explain upward transfer men's high and increasing sense of belonging scores over time. Peer support – another positive predictor of belonging for all students – differed such that upward transfer women reported the lowest scores (though only significantly lower than non-transfer women and non-transfer men). Other findings shown in Table 3 closely mirror those illustrated by Table 2.

Limitations

In order to draw conclusions from the present study, it is important to first recognize several key limitations. First, sample size constraints limited our ability to examine findings across multiple intersecting identities, like gender and upward transfer status together. Second, our sample included only students at research universities, making it unclear the extent to which our findings are representative of upward transfer students enrolled at other institution types, something to explore in future studies. Additionally, our study relied on survey data collected from students who enrolled in an introductory-level computing course and completed a pre- and post-test survey at the beginning and end of their course. This limits the number of upward transfer students surveyed, as we only captured those who had registered for an introductory-level course after transferring. To examine the extent of this limitation, we ran additional analyses to compare our sample to a larger cross-sectional survey of all computing majors at participating research sites; we found that the proportion of upward transfer students among computing majors represented in the present sample was comparable to the proportion of upward transfer students among all computing majors, suggesting that we are capturing typical upward transfer experiences. Perhaps most importantly, upward transfer students are a self-selected group that may have greater expertise than other students (as evidenced by their greater programming experience in the present study). While upward transfer students who successfully arrive at transfer receiving institutions are a critical group to be retained in computing (Blaney, 2020a), it is also critical that we consider who is *not* captured in the present study. To this end, future research should explore students who do not transfer to four-year computing programs, despite being interested in pursuing a four-year computing degree.

Discussion

Our findings highlight the importance of exploring upward transfer students' unique experiences to identify best practices that foster equity in STEM, as upward transfer student experiences may differ substantially from those of other students. To a certain extent, the present findings align with Sax et al.'s (2018) prior study of sense of belonging. As was the case in the 2018 study and other recent research (see Blaney & Stout, 2017; Master et al., 2016; Stout & Blaney, 2017), gender was a consistent predictor of belonging, such that women had lower belonging scores than men, even after accounting for all other variables in the model. Additionally, incoming belonging scores, prior programming experience, departmental support, and peer support were positive predictors of belonging in the present work and the original belonging study. Yet, significant interaction effects show that certain factors uniquely predict sense of belonging for upward transfer students (e.g., time spent using social networking sites). At the same time, positive predictors of belonging for all students (e.g., peer support) are not equally available to upward transfer students. These findings underscore the importance of exploring upward transfer computing students' unique experiences to identify best practices that foster equity in computing, as upward transfer student experiences may differ substantially from those of other students.

Greater programming experience and lower levels of support among upward transfer students

Somewhat surprisingly, upward transfer students did not have lower sense of belonging than other students, which may be because upward transfer students are a self-selected and disproportionately high-achieving group of students in computing (see Laanan et al., 2010; Starobin et al., 2016). In our study, upward transfer students had greater prior programming experience than their peers. Given that prior programming experience is positively associated with sense of belonging in computing (both in the present work, as well as in prior research; Nguyen & Lewis, 2020; Sax et al., 2018), we posit that higher levels of programming experience may have shielded upward transfer students from other inequities. In other words, if not for the fact that upward transfer students brought greater computing expertise with them to their courses, gaps in sense of belonging may have emerged.

Inequities in how students experience four-year computing programs were also apparent. Consistent with other research (Blaney, 2020a), upward transfer students reported lower access to support from other computing students, with upward transfer women reporting the lowest levels of peer support, relative to all other groups. Upward transfer students also reported spending less time socializing, despite the fact that they appear to receive the most benefit from doing so (i.e., time spent socializing positively predicted belonging for upward transfer students). These inequities may be related to the broader culture of transfer receptivity within computing at four-year institutions, something that we discuss further below.

Existing literature may not be representative of upward transfer computing students

Tests for interaction effects identified three variables that uniquely predicted sense of belonging for upward transfer students, each of which were not captured by the original study (see Sax et al., 2018). First, having a parent with a computing career negatively predicted sense of belonging for upward transfer students, but was non-significant for other students in our study. While this is somewhat counterintuitive, we posit that this finding might be related to the types of computing careers occupied by upward transfer students' parents. While data on parents' specific careers are not available, additional analyses show that, of those students who had a parent with a computing career, upward transfer students less frequently reported that the same parent had a bachelor's degree or higher (relative to non-upward transfers). Therefore, we would expect that upward transfer students more frequently had parents working in computing jobs where a bachelor's degree is not required (e.g., some information technology positions), while non-transfers more frequently had parents who were working in computing jobs requiring a bachelor's degree (e.g., programmer). If, for example, upward transfer students' parents more frequently had careers in information technology, while other students more frequently had parents who were programmers, then societal perceptions of what constitutes a *computer scientist* might explain our finding. That is, as upward transfer students are exposed to dominant perceptions of computer science within their four-year computing programs, those who originally had high belonging scores (perhaps due to having a parent with a computing-related career) may have a decreasing sense that they belong in computing. More research is needed to explore the extent to which this might be the case, though prior research supports the notion that parental career generally plays an important role in shaping STEM outcomes (Mannon & Schreuders, 2007).

Additionally, we found that time spent socializing with other students was a positive predictor of belonging for upward transfer students but was nonsignificant for other students. Importantly, participants did not specify with which students they socialize, though it would make sense that more time socializing with computing students may lead to greater sense of belonging. Prior research documents, for example, that socializing with men in STEM contexts "can buffer against belonging-ness threat for women" in STEM (see Holleran et al., 2011, p. 68). In the case of our study, perhaps time spent socializing with other computing students and/or students who followed more traditional pathways to college may protect upward transfer students from threats to their sense of belonging. It is also possible that time spent socializing may be confounded with other key characteristics not

captured by our study. We posit that more research is needed that focuses specifically on upward transfer students to understand the nature of how they interact with other students in computing, and how that, in turn, may shape their sense of belonging.

The third and final significant interaction revealed that time spent using social networking sites negatively predicted feelings of belonging for upward transfer students and was nonsignificant for other students in the sample. This is consistent with prior research suggesting that social media usage can lead to lower sense of belonging among college students, and that the negative effects of social networking are strongest for first-year students who may be most likely to utilize social comparisons to understand their new college experiences (Whillans & Chen, 2018). A similar effect may occur for upward transfer students, who are also navigating new and changing learning environments and may have a propensity to compare themselves to students who followed more direct pathways to their computing program. Despite the negative effect of social media usage in our study, more research is needed to explore possible explanations for this result. Importantly, and somewhat contrary to the present findings, some evidence suggests that social media could actually be a way that college students develop social capital (Ellison et al., 2007), something that should be explored in future studies. Such inquiry may be particularly important for student affairs and higher education professionals seeking to utilize social media to effectively and inclusively support STEM students.

Key implications

Recognizing upward transfer as a mechanism for advancing equity

Prior research documents the important role community college pathways play in broadening participation in computing and other STEM fields (Bahr et al., 2017; Blaney, 2020a; Wang & Wickersham, 2019). Unfortunately, prior studies also show that upward transfer students in computing report lower levels of support from their computing programs and peers – consistent with our findings, though we also found that upward transfer women have the lowest peer support scores of all. Other research on the "transfer penalty" documents ways in which faculty at transfer receiving institutions often fail to recognize that upward transfer students exist in their courses, assuming that all students began their college careers at the receiving institution (Elliott & Lakin, 2020, p. 540). Because "upward transfer students may be a largely invisible group in computing courses" (Blaney, 2020a, p. 258), professional development is needed to help faculty recognize and support this talented and diverse group.

Specifically, while variables related to faculty mentorship and interactions were not significant in the present study, faculty can play a role in fostering peer support in computing, which was a significant predictor of belonging in the present work. As a first step in building a supportive and inclusive peer culture, faculty should recognize that upward transfer students are in their courses, ensuring that content is inclusive of this group. For example, instead of referencing very specific content from prior coursework at the receiving institution (e.g., "Professor X taught you about y in CS1"), instructors should intentionally draw connections to broader types of knowledge that students may have gained, regardless of where they took their earlier courses (e.g., "Some of you may have learned about related concepts such as x; if you took a computing course at another institution, this may have been taught in relation to y or z"). Small changes like this could go a long way in making courses more inclusive, and we recommend that STEM departments provide training and professional development to faculty, so that they can learn to adapt their language and practices in these ways.

Faculty should also work actively to dispel any negative stereotypes about upward transfer students and their abilities. Such stereotypes may have been perpetuated by largely outdated research on "transfer shock" (Hills, 1965, p. 201) and can go unchallenged when faculty and classmates are unaware that some of the highest achieving individuals in their computing courses are upward transfer

students (Blaney, 2020a). In fact, prior research suggests that – despite a temporary dip in performance that sometimes occurs immediately following transfer – students who transfer from a two-year college tend to perform at least as well as, if not better than, their peers who follow more traditional pathways (Carlan & Byxbe, 2000; Laanan, 1996). Sharing such empirical findings with computing faculty and departments may dispel stereotypes about who belongs and has potential to be successful in computing, helping faculty at receiving institutions to recognize the talents and assets that upward transfer students bring with them to computing. In addition, meaningful partnerships between community colleges and four-year institutions can help faculty at receiving institutions understand the needs of upward transfer students by learning from faculty at community colleges. Again, computing departments can offer professional development opportunities to encourage such collaborations. In the long-term, departments might also revise reward structures (e.g., promotion and tenure guidelines) to recognize faculty for collaborating across institutional boundaries and, more broadly, working to improve their practices in support of upward transfer students.

Fostering social support and connections

Given the present findings related to the importance of socializing and being involved in computing-related student groups, computing programs should foster opportunities for students to socialize and gain support. Specifically, departments should ensure that existing programming to support women in computing is inclusive of upward transfer women; likewise, programs for upward transfer students in STEM must also be inclusive of upward transfer women. Prior research provides further context for how practitioners should support students through identity-based organizations within computing and STEM contexts. For example, one recent study of sense of belonging among Latina students in STEM documents the ways in which existing groups for women in STEM are not necessarily inclusive, leading some Latina students to seek community through identity-based groups for Latina/o/x students beyond the STEM context; at the same time, groups specifically for Latinas in STEM serve as valuable spaces where students can develop a sense of belonging that is inclusive of their racial and ethnic identities (Rodriguez & Blaney, 2020). In our study, we found that spending more time in non-computing groups *negatively* predicts sense of belonging, further underscoring the importance of developing community *within* the computing department. Together, our study and other recent research point to the importance of creating spaces where students can develop a sense of belonging in STEM that is inclusive of their multiple and intersecting identities through inclusive programming at two- and four-year institutions alike.

Another way that computing departments or STEM initiatives might seek to build community is through social media. In the present work, it is interesting that time spent using social media negatively predicted belonging for upward transfer students only, while time spent actually socializing with other students was a positive predictor of upward transfer students' belonging. While more research would be needed to deconstruct this finding, we conclude that departments should be careful about how they utilize social media to foster community. While social media can be a useful way to connect with students and increase their access to campus resources (Ellison et al., 2007), a heavy reliance on social media could potentially be detrimental (e.g., time spent connecting with other computing students on social media could lead to negative social comparisons; Whillans & Chen, 2018). Given that much remains unknown about this topic, computing programs might seek feedback on how they are using social media directly from students, ensuring that their feedback includes diverse perspectives (e.g., upward transfer students). More broadly, as institutions implement various initiatives to foster community among students and solicit student feedback, it is important to recognize that many common student affairs programs (e.g., first-year experience) may unintentionally disadvantage upward transfer students by making it harder for them to form social connections with their peers (see Bahr et al., 2013; B. K. Townsend & Wilson, 2006), further underscoring the importance of centering upward transfer students in program development.

Conclusion

While upward transfer students have been identified as a critical group to be recruited and retained in computing majors (e.g., Blaney, 2020a; Hawthorne, 2015; Kahlon et al., 2019), very little research has examined the experiences of upward transfer computing students, and no prior studies have examined how sense of belonging develops for this group. The present study begins to address this gap in the literature by replicating previous research on gender and sense of belonging (e.g., Sax et al., 2018), focusing on upward transfer computing students and upward transfer women more specifically. Findings document three unique predictors of sense of belonging for upward transfer students, pointing to ways in which existing literature has not represented upward transfer student experiences. Finally, access to key predictors of belonging also differed by upward transfer status, gender, and the intersection of these two variables, documenting additional inequities and pointing to implications for practice at community colleges and receiving institutions alike.

Notes

1. None of the participating institutions are located in the Northwest, but the 15 research sites otherwise represent all regions of the United States.
2. A paired sample t-test confirmed that women's belonging did significantly decrease over time, $t(603) = 2.75$, $p = 0.006$.
3. Further analyses using independent sample t-tests reveal that gender gaps in belonging were significant on both the pretest and posttest of sense of belonging (i.e., men had significantly higher belonging scores at both time points), but gaps by upward transfer status were non-significant on the pretest and posttest of belonging.
4. Change in R^2 was significant at every step of the model.

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Appendix

Description of variables

Table A1. Description of variables in regression model.

Measure	Range/Coding	Mean	SD
SENSE OF BELONGING			
DV: Sense of Belonging	3–15 (3-item composite variable)	10.29	2.91
Pretest: Sense of Belonging	3–15 (3-item composite variable)	10.45	2.72
BACKGROUND CHARACTERISTICS			
Upward Transfer Status	0 = Non-UT; 1 = UT	0.15	0.36
Gender	0 = Man; 1 = Woman	0.36	0.48
URM Status	0 = Majority; 1 = URM	0.23	0.42
Major	0 = Non-computing; 1 = Computing	0.49	0.50
Parent Career	0 = Non-Computing; 1 = Computing	0.22	0.48
Programming Experience	0 = No experience; 6 = High level of experience (7-item scale)	1.20	1.10
DEPTARTMENT EXPEREINCES			
Collaborative Pedagogies	3–15 (3-item composite variable)	7.37	3.25
Department Support	4–20 (4-item composite variable)	14.17	3.18
Peer Support	4–20 (4-item composite variable)	12.51	4.46
STUDENT BEHAVIORS			
HPW Non-computing Student Groups	1 = No hours; 8 = 20 or more hours	2.85	1.68
HPW Video Games	1 = No hours; 8 = 20 or more hours	3.10	1.92
HPW Social Networking	1 = No hours; 8 = 20 or more hours	3.56	1.63
HPW Socializing	1 = No hours; 8 = 20 or more hours	4.46	1.66

Only variables that were significant in the regression model are shown in this table. All measures can be found in the original Sax et al. (2018) study. Composite measures are described in more detail in Table A2.

Table A2. Description of composite independent variables.

Variable	Question STEM and Items	Scale	Alpha
Sense of Belonging (pretest)	*Please indicate your agreement with the following statements.* I feel welcomed in the computing community I feel like I belong in computing I do not have much in common with other computing students (reverse coded)	1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly agree	0.72
Leadership Orientation	*How would you rate yourself in the following areas compared to the average person your age?* Public speaking ability Social self-confidence Leadership ability	1 = Lowest 10% 2 = Below average 3 = average 4 = Above Average 5 = Highest 10%	0.77
Social Orientation	*How important to you is it that your future career allows you to do the following:* Help others Have a social impact Serve humanity Give back to my community Be a role model for people in my community Work collaboratively with others	1 = Not at all 2 = Slightly 3 = Somewhat 4 = Quite a bit 5 = Extremely	0.88
Artistic Orientation	*How would you rate yourself in the following areas compared to the average person your age?* Creativity Artistic ability	1 = Lowest 10% 2 = Below average 3 = Average 4 = Above average 5 = Highest 10%	0.69
Family Orientation	*How important to you is it that your future career allows you to do the following:* Spend a lot of time with family Take time off work to care for my family	1 = Not at all 2 = Slightly 3 = Somewhat 4 = Quite a bit 5 = Extremely	0.81
Scholarly Orientation	*How would you rate yourself in the following areas compared to the average person your age?* Academic ability Intellectual self-confidence Mathematical ability Drive to achieve	1 = Lowest 10% 2 = Below average 3 = Average 4 = Above average 5 = Highest 10%	0.71
Collaborative Pedagogies	*How frequently did your computing instructors use the following?* Peer instruction Group work Paired programming	1 = Never 2 = Rarely 3 = Sometimes 4 = Frequently 5 = Always	0.72
Exposure to Relevant Course Content	*How frequently did your computing instructors use the following?* Use of examples involving women Use of examples involving people of color Interdisciplinary connections to computer science Use of real-world problems involving relevant social issues	1 = Never 2 = Rarely 3 = Sometimes 4 = Frequently 5 = Always	0.80
Instructor Inclusivity and Support	Introductory course faculty are inclusive and supportive of women Introductory course faculty are responsive to questions in class Introductory course faculty are interested in helping me when I come to them with questions Introductory course faculty are inclusive and supportive of students of color Introductory course faculty are responsive to e-mail communication	1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly agree	0.90
Frequency Instructor Interactions	*On average, how frequently do you communicate with introductory course faculty in the following ways:* In class At office hours By e-mail By phone call By text messages Via course website In informal meetings (e.g., coffee with a professor)	1 = Never 2 = Less than once per month 3 = 1–3 times per month 4 = 1–3 times per week 5 = More than three times per week	0.77

(Continued)

Table A2. (Continued).

Variable	Question STEM and Items	Scale	Alpha
Department Support	*Please indicate your agreement with the following statements.* I feel a sense of community in the computing department The department cares about its students The environment in the computing department inspires me to do the best job that I can The department is not very supportive of its students (reverse coded)	1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly agree	0.80
Peer Support	*To what extent is each of the following available from other computing students if you need it?* Someone to hang out with Someone to confide in or talk to about your problems Someone to get class assignments for you if you were sick Someone to help you understand difficult homework problems	1 = Not at all 2 = A little 3 = Somewhat 4 = Quite a bit 5 = Very much	0.90

For each composite variable, items were added together to form a scale. All measures were adapted from the original Sax et al. (2018) study.