Understanding Professional Identity Development Among Computer Science Students

Sami N. Rollins, University of San Francisco

Sami Rollins is a Professor of Computer Science at the University of San Francisco (USF). She holds a B.A. in Computer Science from Mills College and M.S. and Ph.D. degrees from the University of California at Santa Barbara.She recently completed a rotation as a Program Director in the Division of Undergraduate Education at the National Science Foundation.

Sami's research interests include broadening participation in computing, computer science education, and mobile and distributed computing. She is currently involved with an NSF-funded S-STEM project that awards scholarships to students studying computing at USF. The project implements a suite of community-building activities designed to improve scholars' self-efficacy and develop computing identity. Sami also co-directed a project that developed system support and user-driven strategies for improving energy efficiency in residential buildings.

Sami has served in a number of service roles at USF and in her professional community. She was chair of the Computer Science department at USF from 2013-2016. She also served on the editorial board of Sigmobile's GetMobile Magazine from 2014-2018. She has been involved with the discipline-specific Networking Networking Women community since 2010, serving as mentor, fellowship co-chair, and workshop co-chair She was co-chair of the board of Networking Networking Women from 2016-2018.

Prof. Alark Joshi, University of San Francisco

Alark Joshi is an Associate Professor in the Department of Computer Science at the University of San Francisco. He was a co-PI on the IDoCode project at Boise State University that provided teacher training, curriculum development, and policy changes in the State Board of Education in the state of Idaho. Currently, he is a co-PI on the S-STEM proposal focused on engaging students in the local community to enable successful outcomes for them with respect to increased self-identity, better grades in courses, and internships/jobs.

He received his Ph.D. in Computer Science from the University of Maryland Baltimore County, his M.S. in Computer Science from the University of Minnesota and his B.S. degree from the University of Pune, India.

Xornam Apedoe, University of San Francisco
Prof. Sophie Engle, University of San Francisco

Sophie Engle is an Associate Professor at the University of San Francisco, where she teaches undergraduate and graduate courses for the Computer Science and Data Science programs. Her current research interests include data visualization and computer science education. She graduated with a Ph.D. on computer security from the University of California, Davis and a B.S. in Computer Science from the University of Nebraska at Omaha.

Prof. Matthew Malensek
Mr. Gian Bruno, University of San Francisco

Work in Progress: Understanding Professional Identity Development Among Computer Science Students

Introduction

Despite growing enrollments in computing programs, retention, particularly of students from historically marginalized and minoritized groups, remains a challenge [1]. Recent research has demonstrated that a stronger sense of disciplinary identity may contribute to increased persistence in STEM fields. A number of High-Impact Educational Practices (HIPs) [2] have been shown to lead to improvements in student success, in general. How these practices affect professional identity development, however, is an area in need of further exploration. In addition, how many of these practices can be applied in the field of computing is not well understood.

The goal of this work is to identify factors that lead to professional identity development among computer science students. Our work focuses on a population of students participating in the Community-Engaged Scholars in Computer Science (**CES|CS**) program at the University of San Francisco (USF)—a mid-sized, private, Jesuit university in San Francisco, California. The **CES|CS** program provides low-income, academically talented students with financial support and programming designed to cultivate computing identity and support success in the computing field. The program's activities integrate a number of HIPs to encourage deeper engagement with the departmental, university, and broader technical communities. By engaging with a variety of communities that provide support, encouragement, and opportunities to develop disciplinary knowledge, the project aims to help students envision themselves as computer scientists.

This work-in-progress reports results from a baseline measure of computing identity. We use two validated survey instruments to measure professional identity among the **CES|CS** scholars and a comparison group of students enrolled in first-semester computing courses. We also conducted follow-up interviews with a subset of the participants. Our analysis considers the extent to which the participants identify as computing professionals; factors that affect the ratings selected across the two instruments; and how participation in the **CES|CS** program influences identity development. We find that students who have been in the program longer demonstrate a greater sense of identity, and we also find that students who identify as female or non-binary selected lower ratings for most of the survey questions. For some of the subconstructs measured by both survey instruments, for example performance and competence, some populations of students gave high ratings on one instrument and low ratings on the other. Our follow-up interviews suggest that, though questions from the two instruments sought to measure the same thing, the students understood the questions differently. Finally, the survey and interview results suggest that the **CES|CS** program is having a positive impact on identity development.

Related Work

This work builds on a body of literature focused on student persistence and success as well as disciplinary identity.

Self-efficacy, Retention, and Academic Support

Perez et al. [3] discuss the impact that professional identity has on retaining students in STEM fields in college. Graham et al. [4] introduced a "persistence framework" that underscores the connection between persistence (especially in STEM fields) with motivation and confidence (self-efficacy [5]). They discuss three factors that form the persistence framework: (i) early access to research in the field, (ii) active learning in the classroom to conduct scientific thinking with their peers, and (iii) participating in *learning communities* [6] / study groups to benefit from peer learning and community building.

Lichtenstein et al. [7] found that when students find the learning environment to be *academically supportive and encouraging*, they are more likely to respond with a stronger commitment to their academic pursuit and degree completion. Wilson et al. [8] include "academic advising, interventions, and individualized development plans" from faculty advisors as one of the key factors that helps students in STEM fields build confidence and stay in the major. Cromley et al. [9] discuss similar themes in their work on student retention. They found that academic support and career counseling can have a big impact on self-efficacy and retention. Xu [10] found that academic integration (participation in organized academic activities with peers, working with students outside class, interacting with faculty outside class concerning coursework) was one of the strongest indicators of student retention in STEM majors.

Zimmerman [11] found that students with high levels of self-efficacy work harder, participate in class, persist longer, and have fewer negative reactions when they encounter difficulties in their major. Lent and Hackett [12] found that self-efficacy has a positive impact on the educational as well as career choices among these students.

Disciplinary Identity

Gee [13] defined identity as "the kind of person one is seeking to be and enact in the here and now." "Being" a STEM professional requires opportunities to demonstrate one's *competence* to others and for them to *recognize* that expertise. Carlone and Johnson [14] identified a model of "science identity" based on the experience of women of color in scientific fields. They differentiate between "student" identity that drives them to earn good grades and "science" identity that requires students to conduct scientific thinking with their peers, and be comfortable with tools and scientific talk. Their model of science identity was based on performance, recognition, and competence.

Garcia et al. [15] discuss "computing identity" among high-achieving students from underserved groups in Computer Science, Computer Engineering, and Information Technology. They found that the women had less of a computing identity as compared to the men and that the students in the Information Technology (IT) program had a lower computing identity than the other students.

These findings were based on a survey instrument that was designed to gauge students' computing identity.

Our work draws upon existing best practices across STEM to implement a holistic model of student support for computing students. We then use two validated survey instruments to measure different facets of computing professional identity development among the participating students.

Community-Engaged Scholars in Computer Science Program

The Community-Engaged Scholars in Computer Science (**CES|CS**) program provides financial support along with programming designed to cultivate computing identity. The project—funded by the National Science Foundation S-STEM program [16]—began at the University of San Francisco (USF) in Fall 2019. **CES|CS** provides four years of support to two cohorts of students: six students who began as first-year students in Fall 2019, and six students who began as first-year students in Fall 2020.

Scholar Recruitment, Eligibility, and Selection In spring of both 2019 and 2020, we solicited applications from all students who were accepted to USF and who met the program criteria. Recruitment included an email campaign, a physical postcard, and posts to our web and social media channels. To be eligible for the program, students must (1) declare a major in computer science; (2) qualify as low-income; and (3) demonstrate academic talent. Students who are eligible to receive a Pell grant are considered low-income by our university. The academic merit criteria require that students meet one of the following requirements: have a high school GPA of 3.0 or higher; have an SAT score of 1250 or higher; or have an ACT score of 28 or higher. The **CES|CS** application included four essay questions that ask students to describe challenges they have overcome and responsibilities they hold outside of academics. A committee of project team leaders evaluated applications and selected students for whom the program has the greatest potential for impact.

During their first two years in the program, scholars participate in several activities designed to help them cultivate computing identity and succeed in the program.

***Head Start* Early Arrival Program** Scholars are required to attend a one-week early arrival program in the week prior to the start of the fall semester. *Head start* is designed to encourage cohort building, to introduce students to resources available to them in the department and at the university, and to expose them to some of the technical content they encounter in the first semester of study. The program runs six hours per day and activities include programming instruction and practice; presentations by representatives from campus resources such as the writing center; and an opportunity to meet faculty in the department via a scavenger hunt. In 2019, the program took place in person and included a field trip to a local technology company. Scholars were also permitted to move into the campus dormitories one week early for the program. Because of COVID restrictions, in 2020 the program took place online and students participated from their homes.

CS 186: A Two-Credit Introduction to the Computing Community In the fall semester of the first year, we offer a two-credit course designed to help scholars become integrated into the departmental and local technical communities. Scholars are strongly encouraged to take the course; however, because of scheduling conflicts, two scholars—one from each cohort year—have been unable to participate. This course is also open to up to 10 non-scholars, with a total enrollment of 15. Class activities include talks and panels featuring alumni; workshops on professional tools such as LinkedIn; and presentations by representatives from campus resource organizations such as the counseling center. A highlight of the class in 2019 was several field trips to local technology companies, however in 2020 COVID restrictions required us to replace this activity with more opportunities to interact with alumni via Zoom.

Cohort Enrollment Students are encouraged to enroll in the same sections of their computer science major courses during the first two years of study. This is not always possible, however, since students enter the major with differing backgrounds. Some start in our CS 0 course for non-majors, some start in our CS 1 course for majors, and some may have AP credit that allows them to start in CS 2. Like many computing departments, our major is impacted and classes fill quickly. Scholars, however, are guaranteed a seat in the recommended cohort sections of their major courses.

One-on-One Faculty Mentoring In addition to their departmental academic advisor, scholars are assigned one of the project leaders as a faculty mentor. Scholars are encouraged to connect with their mentor if they have any questions about the department, major, or university. In practice, the project leaders work as a team, and scholars are encouraged to reach out to any of the project team leaders anytime they have questions or concerns.

Ongoing Check-ins Though not part of the originally-proposed program, in fall 2020 we began a bi-weekly check-in meeting with the 2019 scholars. We recognized that there were no formal opportunities for the scholars to meet as a group during the second year of study. We also recognized that the COVID pandemic and remote learning environment were likely to be causing additional stress for the scholars. Thus, every two weeks the four faculty project leaders meet with the six scholars for an informal opportunity to discuss any questions or concerns.

In Fall 2021 we will begin the junior- and senior-level programming. Activities to be introduced in the last two years of study include a career preparation course, alumni mentoring, technical conference attendance, and a computing-specific service learning course.

Method

The goal of the **CES|CS** program is to help students succeed in the computing major and become professionals in the computing field by encouraging development of computing identity. This work-in-progress seeks to understand the trajectory of students' computing identity development and how the program's activities contribute to the process.

Participants

We invited participation from the following three populations of students:

- **Cohort 1**: six scholars who began as first-year Computer Science majors in Fall 2019.
- **Cohort 2**: six scholars who began as first-year Computer Science majors in Fall 2020.

Participant Group		Gender Identity		Racial/Ethnic Identity	
Cohort 1	3	Female	12	Asian	7
Cohort 2	3	Male	12	Black/African American	5
Comparison Group	20	Other/Nonbinary	2	Hispanic or Latino	4
				Native Hawaiian/Pacific Islander	1
				White/Caucasian	8
				Other	1

Table 1: Demographics of all students who responded to the the start-of-semester survey for Fall 2020. Across the scholars (Cohort 1 and Cohort 2), there were three participants who identify as Female and three participants who identify as Male. The Comparison Group included nine participants who identify as Female, nine who identify as Male, and two who identify as Other/Nonbinary. The scholar group also included two students who identify as Asian, two students who identify as Black/African American, one student who identifies as Hispanic or Latino, and one student who identifies as White/Caucasian.

Participant Group		Gender Identity		Racial/Ethnic Identity	
Cohort 1	3	Woman	6	Asian	4
Cohort 2	2	Man	5	Black/African American	2
Comparison Group	6			Hispanic or Latino	2
				White/Caucasian	3

Table 2: Demographics of all students who responded to both the start-of-semester and end-of-semester surveys for Fall 2020. Across the scholars (Cohort 1 and Cohort 2), there were three participants who identify as Women and two participants who identify as Men. The Comparison Group included three participants who identify as Women and three who identify as Men. The scholar group also included two students who identify as Asian, one student who identifies as Black/African American, one student who identifies as Hispanic or Latino, and one student who identifies as White/Caucasian. Analysis in the Results section considers only end-of-semester responses from students who also responded to the start-of-semester survey.

- **Comparison Group**: 49 students enrolled in first-semester computer science classes in Fall 2020. Students from one section of CS 0, one section of CS 1, and the CS 186 class offered as part of the **CES|CS** program were invited to participate. Cohort 2 scholars were enrolled in both the CS 0 and CS 1 sections from which Comparison Group participants were drawn.

The demographics of the students who opted to participate are described in Table 1 and Table 2. We initially began to collect demographic data using the question *With which gender do you most closely identify?* and provided options `Male`; `Female`; `Other, please specify` (with a text box); and `Prefer not to specify`. We have since modified our approach to follow the guidance by Spiel, Haimson, and Lottridge [17] who recommend providing the following choices for collecting information about gender identity: `woman`, `man`, `non-binary`, `prefer not to disclose`, and `prefer to self-describe`. Our results do include a category `Other` because of the initial approach.

Instruments

We use two existing, validated instruments to collect a baseline measure of computing identity. The Conceptual Understanding & Physics Identity Development (CUPID) [18] survey, shown in Table 3, asks nine questions to assess students' perceived recognition, interest and performance/competence. The adapted version of the STEM Professional Identity Overlap (STEM-PIO) [19] measure uses a pictorial representation to assess perceived recognition, performance, competence, typicality, and centrality. The modified pictorial representation used in our study is shown in Figure 1, and the prompts given to students are shown in Table 4.

CUPID Subconstruct	**Question**
Recognition	My family sees me as a computer-savvy person. My friends/classmates see me as a computer-savvy person. My instructors/teachers see me as a computer savvy person.
Interest	Topics in computing excite my curiosity. I like to peruse forums, social media, or online videos about computer-related topics. Computer programming is interesting to me.
Performance/ Competence	I can do well on computing tasks (e.g. programming and setting up servers). I understand concepts underlying computer processes. Others ask me for help with software (applications/programs).

Table 3: Questions from the CUPID survey instrument.

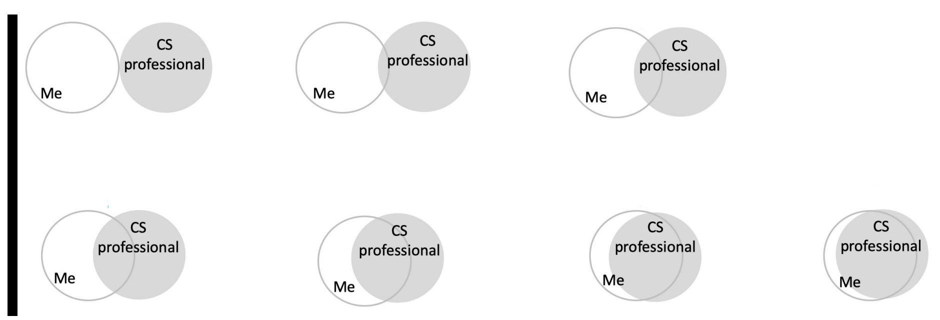

Figure 1: We use an adapted version of the STEM Professional Identity Overlap (STEM-PIO) instrument that replaces "STEM Professional" with "CS Professional".

Procedure

The participants were sent an email message inviting them to complete the surveys via Qualtrics. After consenting to participate, students were asked the CUPID questions followed by the STEM-PIO questions. Finally, we asked for demographic information including gender identity, race/ethnicity, Pell eligibility, and level of parental education. The survey was administered at the beginning of the fall semester, in August 2020, and at the end of the fall semester, in December 2020. The December survey asked students whether they would be willing to participate in a

STEM-PIO Subconstruct	Modified Prompt
Interpersonal Closeness	Select the picture that best describes the current overlap of the image you have of yourself and your image of what a CS professional is.
Competence	Select the picture that best describes the extent to which your knowledge of CS concepts matches that of a CS professional.
Performance	Select the picture that best describes the extent to which your capacity to use CS skills in a public setting matches that of a CS professional.
Recognition	Select the picture that best describes the extent to which you think others (such as your CS professors) see your identity as overlapping with a CS professional.
STEM Centrality	Select the picture that you feel best represents your level of identification with CS professionals as a group.

Table 4: Prompts for the survey adapted from the STEM-PIO instrument.

follow-up interview to provide more context about their responses. Two students from Cohort 1 and one student from Cohort 2, two women and one man, participated in a 30-minute interview conducted in January 2021. During the interview, we asked the students questions related to Performance/Competence, Recognition, and Interest.

Results

Our analysis is guided by three research questions:

1. To what extent do the respondents identify as computing professionals, and how is professional identity development affected by gender identity and length of time in the program?
2. What are the factors that lead students to rate the Performance and Competence questions from the two instruments differently?
3. How does participation in the **CES|CS** program influence development of computing identity?

Figures 2, 3, 4, and 5 illustrate the means across responses for all questions from the CUPID and STEM-PIO survey instruments administered in August 2020. The CUPID survey is on a 0–4 scale, and we coded the STEM-PIO responses on a 1–7 scale where 1 represents the picture with the least overlap and 7 represents the picture with the most overlap.

To what extent do the respondents identify as computing professionals, and how is professional identity development affected by gender identity and length of time in the program?

Students who have been in the program longer gave the highest ratings for the questions from the CUPID survey instrument. The Cohort 1 students gave high ratings of 3 or 4 for most of the CUPID survey questions. The Cohort 2 and Comparison Group students rated the Interest

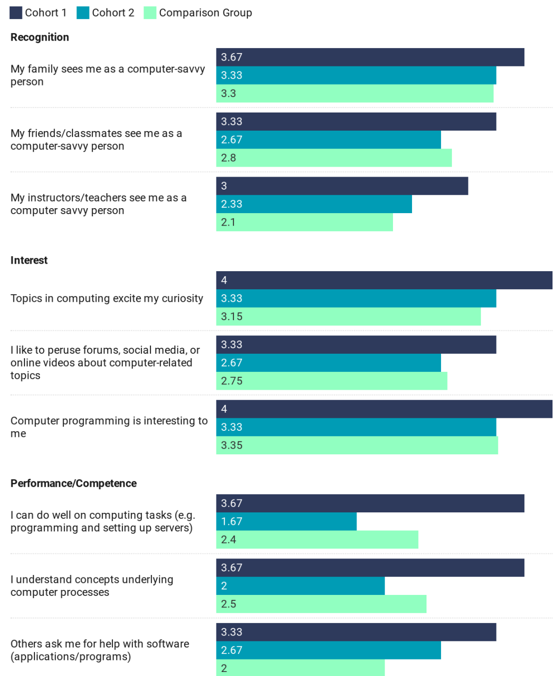

Figure 2: Mean rating for Cohort 1 (n=3); Cohort 2 (n=3); and the Comparison Group (n=20) for the August 2020 responses to the CUPID survey questions.

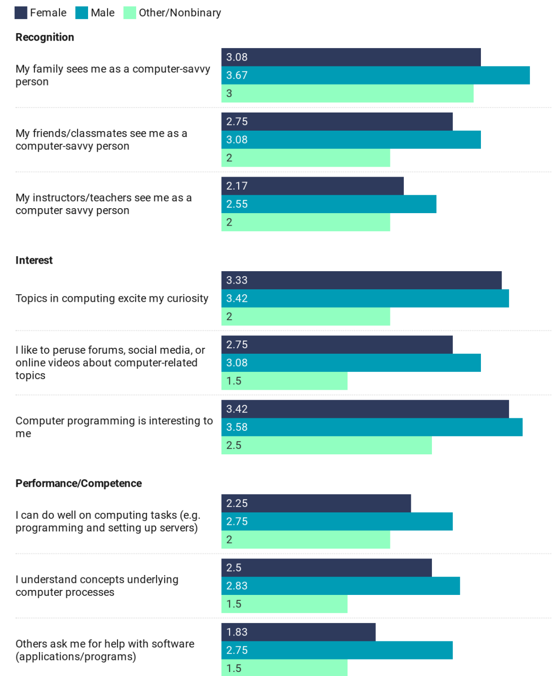

Figure 3: Mean rating for Female (n=12); Male (n=12); and Other/Nonbinary (n=2) for the August 2020 responses to the CUPID survey questions.

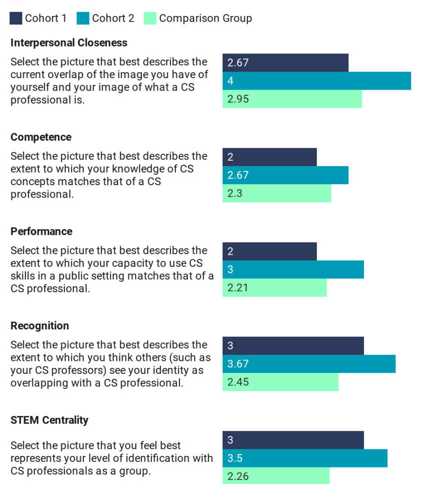

Figure 4: Mean rating for Cohort 1 (n=3); Cohort 2 (n=3); and the Comparison Group (n=20) for the August 2020 responses to the STEM-PIO survey questions.

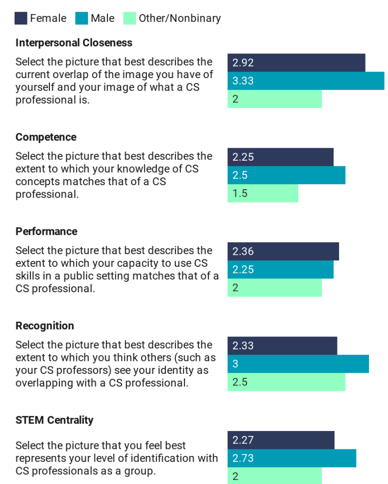

Figure 5: Mean rating for Female (n=12); Male (n=12); and Other/Nonbinary (n=2) for the August 2020 responses to the STEM-PIO survey questions.

and Recognition questions highly, however scores of 0, 1, and 2 were common for the Performance/Competence questions. The three questions with the lowest overall mean scores—two from the Performance/Competence category and one from the Recognition category—were as follows: `Others ask me for help with software (applications/programs)` (mean 2.23); `My instructors/teachers see me as a computer savvy person` (mean 2.32); and `I can do well on computing tasks (e.g. programming and setting up servers)` (mean 2.46). In comparison to the results reported by Garcia, et. al. [15], our absolute results were lower. However, like they observed, in our study the Interest category had the highest mean of 3.167, followed by the Recognition category with a mean of 2.84, followed by the Performance/Competence category with a mean of 2.42.

Surprisingly, **the Cohort 1 students rated the STEM-PIO questions lower than the Cohort 2 students in all cases and lower than the Comparison Group for three out of five questions.** We do acknowledge that our sample size is small and may impact our results. In addition, we did not begin collecting these data until August 2020, thus we do not have data for Cohort 1 in their first year of study. We note, however, that the Cohort 1 students selected the lowest ratings on the STEM-PIO Competence and Performance questions despite high ratings for the Performance/Competence questions on the CUPID survey. Our interviews shed some light on this discrepancy, and we discuss those results in more detail below.

Our next observation is that **students who identify as female or non-binary gave lower ratings than students who identify as male for the CUPID questions related to Performance/Competence, however their ratings for the STEM-PIO Performance and Competence questions were nearly the same as or higher than the male-identified students.** Like Garcia, et. al. [15], we observe that female-identified students had lower ratings than male-identified on all CUPID questions, and ratings of the two students who identified as Other (one student self-described as non-binary) were lower still. Again, however, we see an inconsistency in the ratings selected for the Performance/Competence questions across the two surveys. We did look at the effect of race/ethnicity, however there were no clear findings given the small sample size.

Finally, recognition by others has been described as critically important to developing science identity [14], and **our results from both surveys suggest a need for improvement in how we develop recognition among students, particularly those who identify as female and non-binary.** Interestingly, both of the female-identified students we interviewed explained that they do feel recognized as future computer scientists by friends and family, especially those who are not computer scientists. When asked whether her friends see her as a future computer scientist, one student replied that, because she is the only person in her friend group pursing a STEM major, her friends "definitely do see me as" a computer science major. Similarly, another student said, "I think, definitely, yes, more so people that aren't aware of what a computer science person does." These comments provide us with evidence to suggest that connecting students with community beyond the technical community may be important for developing recognition. We anticipate that the service learning experience the scholars will participate in during the junior or senior year will help with this development.

What are the factors that lead students to rate the Performance and Competence questions from the two instruments differently?

During our interviews, we sought to understand why students may have rated the Performance and Competence questions from the two instruments differently. We verbally asked students to rate the questions from both surveys and to explain how they feel their knowledge and skills differ from that of a CS professional. Our results suggest that, **though both instruments seek to measure Performance/Competence, the students understood the corresponding questions from each survey to mean different things.**

The knowledge and skills that the students associated with a CS professional were different from the specific examples given in the CUPID survey questions. During the interview, one student gave low ratings for the CUPID Performance/Competence questions, but described other skills she has that she feels overlap with those of a CS professional. She explained that "problem solving" is something she feels she is good at. When asked for her ratings on two of the CUPID Performance/Competence questions, she said she would rate them low; however, when asked to compare her skills to that of a CS professional she explained that the "skills part of it, just, I mean, being able to kind of solve those kind of problems, I feel like I'm pretty good at that." Despite high scores for the CUPID Performance/Competence questions, one student gave a low rating (2 on a 0–4 scale) for the knowledge overlap with a CS professional question "based on what's actually needed for day-to-day professional work." When asked what he thought he still needed to learn he said, "designing things"; "considering how to make it more scalable or efficient"; "significant group project which requires collaboration"; and "improving quality of code and design". Both of these examples offer evidence that students have a broad view of what a CS professional knows and can do. In the case of the first student, she feels she has those broader skills but still needs to learn the most specific skills cited in the CUPID survey. In the case of the second student, he feels he has the specific skills cited by the CUPID survey but still needs to learn many of the broader skills.

The students also offered some additional perspective on how **the specific examples provided in the CUPID questions were a factor in the ratings given.** When asked to rate the statement `I can do well on computing tasks (e.g., programming and setting up servers).` one student said, "you threw in the servers and that threw me off." Another student chose a rating of 1 or 2 and explained, "I don't necessarily understand what setting up a server entails." These responses suggest that the inclusion of `setting up servers` as an example had an impact on the ratings for this question. When asked how well he understands the concepts underlying computer processes one student said he would rate his understanding a 3 on a 0–4 scale and explained, "there's a lot of underlying stuff in the systems class that we covered that was not...there was a lot of details." He went on to say, "in architecture and other classes I'll be closer to a 4." It is unclear whether he understood `computer processes` to mean something specifically related to computer processors or hardware. In both cases, his responses suggest that the level of specificity of the CUPID questions was a factor in his ratings.

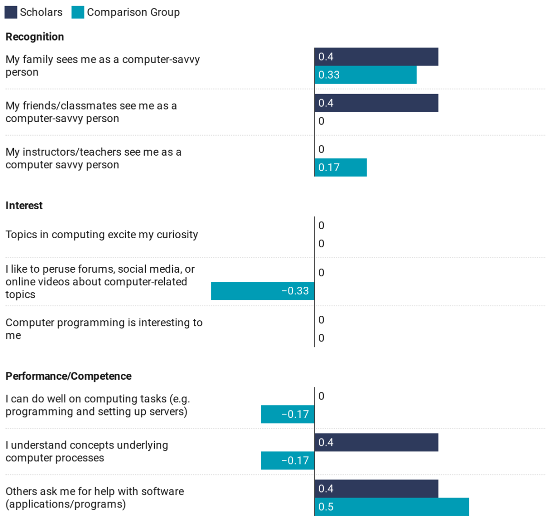

Figure 6: Change in rating between August and December for the scholars (n=5) and the comparison group (n=6) for the CUPID survey questions. The results show only ratings by students who responded to both surveys.

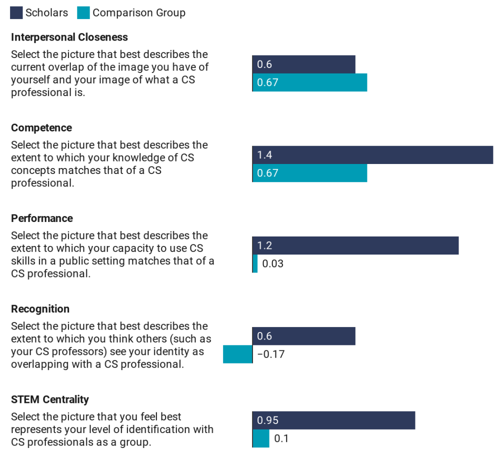

Figure 7: Change in rating between August and December for the scholars (n=5) and the comparison group (n=6) for the STEM-PIO survey questions. The results show only ratings by students who responded to both surveys.

How does participation in the ***CES|CS*** *program influence development of computing identity?*

Figures 6 and 7 illustrate the change in mean rating for all questions on both instruments across students who responded to both surveys. The figures compare the responses of scholars from both cohorts to students from the comparison group. **For all questions, the mean ratings increased between August and December for scholars who responded to both surveys.** For almost all questions, scholars reported a more significant increase in rating than students from the comparison group. Students from the comparison group did report a decrease in rating for three questions from the CUPID survey and one question from the STEM-PIO survey. Though these results suggest areas for improvement for our major, in general, they provide some evidence that the **CES|CS** program is having a positive impact.

We acknowledge that three months may be too short a period to see meaningful development in computing identity, and we also acknowledge that the scholars may have had greater interest in and experience with computing prior to joining the program. The latter is supported by our interviews. All three scholars who participated in interviews described becoming interested in computing in high school or before, and all also had some experience learning to code or taking AP computer science classes. Still, **all scholars interviewed reported an increase in interest since joining the program.** One scholar, for example, said her interest "definitely increased because as I learn more CS, and as I'm able to do more, it just gets more fun." Another described how the CS 186 class, in particular, contributed to her increase in interest. She explained that it showed "different paths that I could take to become a computer science professional, and I could see myself in a lot of those paths."

The interviewees also described how the cohort-based activities have contributed to their identity development. When asked whether her classmates see her as a future computer scientist one student said, “I’m going to use classmates as the people that are also in the scholarship program, and I think we all kind of see each other as being able to make it to that point. We can recognize each other’s skills and aptitudes for being a computer science major and then a professional later on.” Similarly, another student described the cohort as “this community of people that I can always rely on” and said “I think we’re all excited for each other to see what we do, what we end up doing.”

Discussion

Though it is still early in the program, the survey results and interviews provide evidence that the **CES|CS** program is having a positive impact on computing identity development. This work, however, has demonstrated a need to more carefully consider how we support identity development among non-scholars, particularly those who identify with some groups historically marginalized in computing. We did not expect that questions about the same subconstruct would result in different ratings across the two instruments; however, this finding indicates that using multiple instruments to measure identity development may lead to a broader understanding. In our future work, we plan a more detailed exploration of student perceptions of the questions across the two instruments. We will continue to administer both instruments annually to understand students’ long-term trajectories and identify which factors have the greatest impact on development of identity. By better understanding identity development, we can work to improve persistence in computing programs.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. 1833718. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

[1] G. Kena, L. Musu-Gillette, J. Robinson, X. Wang, A. Rathbun, J. Zhang, S. Wilkinson-Flicker, A. Barmer, and E. D. V. Velez, “The condition of education 2015. nces 2015-144.” *National Center for Education Statistics*, 2015.

[2] “AAC&U high-impact educational practices,” https://www.aacu.org/node/4084, accessed: 2020-02-11.

[3] T. Perez, J. G. Cromley, and A. Kaplan, “The role of identity development, values, and costs in college STEM retention.” *Journal of educational psychology*, vol. 106, no. 1, p. 315, 2014.

[4] M. J. Graham, J. Frederick, A. Byars-Winston, A.-B. Hunter, and J. Handelsman, “Increasing persistence of college students in STEM,” *Science*, vol. 341, no. 6153, pp. 1455–1456, 2013.

[5] D. H. Schunk and F. Pajares, “Competence perceptions and academic functioning,” *Handbook of competence and motivation*, vol. 85, p. 104, 2005.

[6] M. Dagley, M. Georgiopoulos, A. Reece, and C. Young, “Increasing retention and graduation rates through a STEM learning community,” *Journal of College Student Retention: Research, Theory & Practice*, vol. 18, no. 2, pp. 167–182, 2016.

[7] G. Lichtenstein, H. Loshbaugh, B. Claar, T. Bailey, and S. Sheppard, “Should I stay or should I go? Engineering students’ persistence is based on little experience or data,” in *Proceedings of the American Society for Engineering Education Annual Conference*, 2007, pp. 24–27.

[8] Z. S. Wilson, L. Holmes, K. Degravelles, M. R. Sylvain, L. Batiste, M. Johnson, S. Y. McGuire, S. S. Pang, and I. M. Warner, “Hierarchical mentoring: A transformative strategy for improving diversity and retention in undergraduate STEM disciplines,” *Journal of Science Education and Technology*, vol. 21, no. 1, pp. 148–156, 2012.

[9] J. G. Cromley, T. Perez, and A. Kaplan, “Undergraduate STEM achievement and retention: Cognitive, motivational, and institutional factors and solutions,” *Policy Insights from the Behavioral and Brain Sciences*, vol. 3, no. 1, pp. 4–11, 2016.

[10] Y. J. Xu, “Attention to retention: Exploring and addressing the needs of college students in STEM majors.” *Journal of Education and Training Studies*, vol. 4, no. 2, pp. 67–76, 2016.

[11] B. J. Zimmerman, “Self-efficacy: An essential motive to learn,” *Contemporary educational psychology*, vol. 25, no. 1, pp. 82–91, 2000.

[12] R. W. Lent and G. Hackett, “Career self-efficacy: Empirical status and future directions,” *Journal of vocational Behavior*, vol. 30, no. 3, pp. 347–382, 1987.

[13] J. P. Gee, “Chapter 3: Identity as an analytic lens for research in education,” *Review of research in education*, vol. 25, no. 1, pp. 99–125, 2000.

[14] H. B. Carlone and A. Johnson, “Understanding the science experiences of successful women of color: Science identity as an analytic lens,” *Journal of Research in Science Teaching*, vol. 44, no. 8, pp. 1187–1218, 2007. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1002/tea.20237

[15] A. Garcia, M. Ross, Z. Hazari, M. A. Weiss, T. Solis, and M. Taheri, “Examining the computing identity of high-achieving underserved computing students on the basis of gender, field, and year in school,” in *2018 CoNECD - The Collaborative Network for Engineering and Computing Diversity Conference*. Crystal City, Virginia: ASEE Conferences, April 2018, https://peer.asee.org/29535.

[16] “NSF scholarships in science, technology, engineering, and mathematics program (S-STEM),” https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5257, accessed: 2020-11-16.

[17] K. Spiel, O. L. Haimson, and D. Lottridge, “How to do better with gender on surveys: A guide for HCI researchers,” *Interactions*, vol. 26, no. 4, p. 62–65, Jun. 2019. [Online]. Available: https://doi.org/10.1145/3338283

[18] J. Mahadeo, Z. Hazari, and G. Potvin, “Developing a computing identity framework: Understanding computer science and information technology career choice,” *ACM Trans. Comput. Educ.*, vol. 20, no. 1, Jan. 2020. [Online]. Available: https://doi.org/10.1145/3365571

[19] M. M. McDonald, V. Zeigler-Hill, J. K. Vrabel, and M. Escobar, “A single-item measure for assessing STEM identity,” *Frontiers in Education*, vol. 4, p. 78, 2019. [Online]. Available: https://www.frontiersin.org/article/10.3389/feduc.2019.00078