Diversity Across a Decade: A Case Study on Undergraduate Computing Culture at the University of Illinois

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ABSTRACT

While we celebrate the dramatic increase in women's undergraduate enrollment at computer science programs around the country, to see this surge translate into career-long outcomes, we cannot ignore ongoing gendered and racialized disparities in computing, particularly as they relate to a student's sense of belonging. Even in times of high enrollment, fostering a sense of belonging cannot occur just through ad-hoc methods, the goodwill of a few faculty, or a standalone mentoring program. Policies and structures must be put into place and enacted holistically.

We report on a multi-phase, 10-year case study of undergraduate student experiences at the University of Illinois (2007, n=61; 2017, n=339). Our 2017 study explores the policies and structures enacted over a decade and their impact on departmental culture. We report on three areas: i) Inclusive classroom experiences; ii) Quality of mentorship opportunities; iii) Student sense of identity. While there have been significant departmental improvements, there are some cultural, policy, and structural issues to be addressed in order to foster a sense of belonging and success for all students.

CCS CONCEPTS

• **Social and professional topics → Computer science education**;

KEYWORDS

Diversity, case study, mentorship, professional teaching track

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1 INTRODUCTION

Ten years ago, we conducted a culture study of the Computer Science Department at the University of Illinois at Urbana-Champaign, a large research institution ranked among the top in the country. At the time, we found that the emphasis placed on research was at the cost of students' sense of belonging. Students did not perceive that the department valued teaching excellence. Undergraduate mentorship and research opportunities were limited, and students felt isolated from the department faculty and from each other [5].

In 2008, authors Crenshaw, Chambers, and Metcalf provided four recommendations to the Computer Science Department with respect to fostering undergraduate sense of belonging [7]:

(1) Facilitate more interaction between students and faculty.
(2) Improve quality of teaching.
(3) Increase early research opportunities.
(4) Create multiple and diverse mentoring opportunities.

Quoting a letter of support from the 2016 Computer Science Department Head [23], the specific changes informed by our original study included:

(1) A formal teaching requirement for all Ph.D. students.
(2) Significant improvements in undergraduate advising policies, including an assigned Faculty Mentor to every undergraduate as well as two full time student-facing academic professionals.
(3) Professionalization of our instructional faculty, including well-defined promotions paths, persistent course assignments – All introductory undergraduate courses are now assigned to faculty whose primary focus is teaching.

It is worth noting that other significant changes have occurred. In particular, enrollments have almost tripled, from 650 in 2005 to 1686 in 2016. At the same time the proportion of women enrolled in the program has increased from 9% to 24%. This is due, in part, to the recent dramatic increases of women's enrollment into computer science programs, reported at multiple institutions [11, 22, 24]. The racial demographics have also changed. The department has larger populations of Asian and International students. That said, other racial categories have not changed much, with African American and Hispanic student populations hovering at 1-4%.

In this paper, we report on a follow-up study to our original work. We investigate how these changes have affected the attitudes and perceptions of undergraduates now enrolled in the CS

department. Our larger study investigates undergraduate, graduate, and faculty experiences in the department via surveys and one-on-one interviews. For the purposes of this paper, we focus primarily on our survey findings from the undergraduate student data. In particular, we explore undergraduate students' sense of identity, mentorship and mentoring opportunities, and teaching. After sharing our findings and relating them to those uncovered in 2006, we discuss lessons learned over the past ten years and offer future directions for improvement. It is our hope that other computing departments can learn from our findings, apply our recommendations within the context of their own organizations, and gain valuable insights about the role of such data collection efforts in informing programmatic, practical, and policy changes that benefit their entire community and bolster their recruitment and retention efforts.

2 RELATED WORK

Computer Science undergraduate enrollment and degree attainment have been of interest for many decades. Foremost, women and people of color are miserably underrepresented among bachelor's degree earners in Computer Science. In 2013, women earned 50.3% of science and engineering bachelor's degrees but only 18% of bachelor's in Computer Science [3].

Much research has explored why these differences exist. Underrepresented groups are particularly likely to feel a lack of fit or expertise compared to their peers [4, 18]. Exacerbating this is extensive evidence of cultural barriers and biases experienced by members of these groups that not only influence sense of fit, self-efficacy, and scientific identity, but also influence every core aspect of their scientific career pathway including classroom experiences, internship opportunities, mentoring experiences, hiring, evaluation, access to funding, promotion, salary, and more [10, 13, 17, 18].

While many efforts have attempted to address this problem through interventions to provide tools, support, and resources to women and people of color in scientific fields, research illustrates that these efforts are limited in their ability to effect the kinds of long-term, sustainable change needed to truly address the root of this problem [2, 4, 17]. Instead, this body of work suggests the necessity of engaging in transformative work at a cultural level in order to impact meaningful change [8, 12, 16, 19, 21].

Universities are reporting significant growth in women's enrollment in Computer Science programs around the country [22, 24]. Among these is the University of Illinois at Urbana-Champaign where 46% of its 2016-2017 incoming freshman class was comprised of women [11]. Our hope is that, through this study's findings and recommendations, we can foster a culture in which the department's recruitment endeavors can expand into positive retention outcomes for all of its students.

One of the few of its kind, this article presents a 10-year, multi-phase case study. Except for the landmark study, "Unlocking the Clubhouse" performed at Carnegie Mellon University [15], we are unaware of other such longitudinal studies. Smaller-scale studies, however, have examined specific departmental issues, such as student retention through a curriculum [1].

	Undergraduate Population		Survey Participants	
	2005-2006	2016-2017	Spring 2017	
Total	650	1686	339	222[1]
Men	90.9%	75.6%	39.8%	60.8%
Women	9.0%	24.3%	24.8%	37.8%
Gender Minorities[2]	n/a	n/a	0.9%	1.4%
White	64.7%	27.5%	27.4%	41.9%
African American	1.3%	1.4%	0.3%	0.5%
Asian	20.9%	36.2%	32.4%	49.5%
Hispanic	4.1%	3.7%	0.6%	0.9%
Native American	0.0%	n/a[3]	0.3%	0.5%
Multiracial	n/a[4]	2.6%	4.1%	6.3%
International	6.9%	27%	17.1%	26.1%
Unknown	1.8%	1.0%	34.5%	n/a

Notes:
1. The gender and racial identity questions were not required questions in our survey. Of the 339 participants, 222 answered survey questions about gender and racial identity.
2. The Illinois Computer Science Department does not track gender minorities such as genderqueer or transgender.
3. The percentage of Native American students were too few to report by the Illinois Computer Science Department as it would allow individuals to be identified.
4. The Illinois Computer Science Department did not track "Multiracial" as a racial identity in the 2005-2006 academic year.

Figure 1: A comparison of the undergraduate demographics at the time of the original study and our 2017 study.

3 RESULTS

3.1 Methodology

We conducted this follow-up study in two-phases during Spring 2016 - Fall 2017 at the Department of Computer Science under Institutional Review Board project 16507. In the pilot phase, we updated and tested our survey instruments and interview protocols via 60 to 90 minute sessions with participants. Our preliminary findings from the pilot study are available in [6].

We then revised the instruments according to pilot feedback and launched the 63-question on-line survey, inviting the entire enrolled undergraduate student population to participate via e-mail from representatives of the department's academic office. Except for two questions necessary for consent, no question on the survey was required; participants were allowed to skip questions.

For the Spring 2017 study, survey questions covered a variety of topics about student experiences in the department, including: their pathway to the department, coursework and attendance, quality of teaching and instruction, advising needs and experiences, mentoring, sources of support, sense of fit and belonging, extracurricular activities and free time, departmental values and culture, future plans, and demographics. We expanded our demographic questions and response options to incorporate write-in answers that we received in the original study and to use more inclusive categories for social identities, such as race, ethnicity, gender, disability, and sexuality, than are typically included in such surveys. As in the original study, each topical area within the survey included open-ended

response options so students could openly share their experiences with that topic. Many questions also included "other, please explain" options to provide space for students to offer up responses that best reflect their experiences, perspectives, and identities. These open-ended responses provided a rich source of qualitative data and additional context and depth to the quantitative data.

At the time of the Spring 2017 study, the department had 1686 undergraduates. As summarized in Figure 1, the department comprised 24.3% women. Among students of color, the department saw 1.4% African American students, 36.2% Asian students, and 3.7% Hispanic students. In total, 339 undergraduates participated in the survey, representing a 20.7% response rate from the 2016-2017 undergraduate population. Among these participants, 222 fully completed the demographic section of the survey. In reporting our findings in the following sections, we use this sub-sample when sharing trends disaggregated by demographic categories.

3.2 Inclusive classroom experiences

In our original 2006 survey of undergraduates, students were asked the following yes-no question about teaching, "Do you think that the computer science department values excellent teaching?" Of the 61 participants, 21 answered "No". We asked a similar question in our Spring 2017, this time allowing students to answer "somewhat". Only 10 out of 334 undergraduates answered "no" to the same question. Figure 2 compares these results.

Figure 2 compares the results. We acknowledge that the questions differ in response options. That said, the large number of "somewhat" responses and the qualitative responses then and now indicate a shift in undergraduates' perception of how teaching is valued by the department. In our original study, comments and suggestions on improving the teaching quality in the department were one of the most heavily discussed topics both in interviews and the survey [7].

Looking at students' qualitative comments in the Spring 2017 survey, we see this shift in perception of teaching:

"I think we have many excellent professors, especially in lower level classes/required classes. This has helped increasing students' interest in the subject tremendously."

"I've had 1 experience where I wasn't happy with my instructor. Other than that I was almost always left in awe of the dedication and love that the instructor had for the subject and for teaching."

It is likely the teaching-track faculty had significant impact on these feelings, especially given the number of undergraduates who specifically named these faculty members in their comments. In addition, as reported in our preliminary findings [6], extra training for graduate student teaching assistants has been incorporated into the program. During the pilot, many graduate students commented that such training was both useful and a strong indicator that the department valued teaching and their role as teaching assistants.

In both studies, students answered, "When you miss a class, what are the reasons motivating you to be absent? (check all that apply)" using the options in Figure 3. In 2006, 66% of students said, "I do not feel that the lectures help me learn", as opposed to only 21% in 2017. Similarly, for the statement "I do not like the teaching style of the lecturers", the original study had 49% who agreed, while the more recent survey has only 15% who agree.

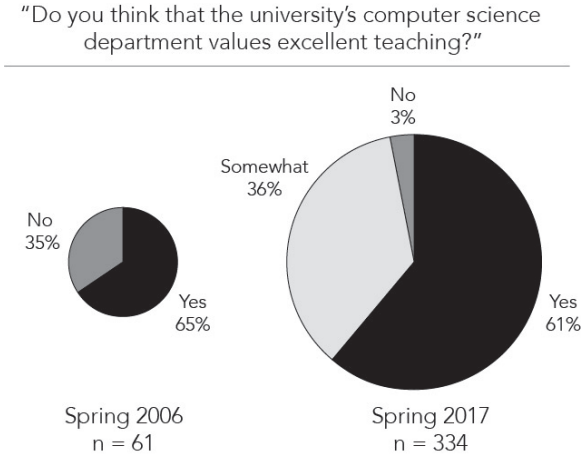

Figure 2: A comparison of the undergraduate perceptions of teaching excellence in 2006 and 2017.

However, some students do comment on issues that detract from the classroom experience, citing examples such as class sizes or professors who are more invested in research. Almost all student comments recognize the non-tenure track instructors as being gifted and innovative teachers, reinforcing our hypothesis that investing in such a track has improved student classroom experiences.

"When you miss a class, what are the reasons motivating you to be absent? (check all that apply)"

	Spring 2006	Spring 2017
I only miss a lecture if I'm unwell.	N/A	41%
I do not have time to attend all the lectures.	25%	35%
I do not feel that the lectures help me learn.	66%	41%
I do not like the teaching style of the lecturers.	49%	29%
I prefer to watch lecture videos.	8%	31%
Other. Please explain:	58%	17%

Figure 3: A comparison of undergraduate motivations to miss lectures in 2006 and 2017.

On the other side, many undergraduates made negative comments about the quality of teaching from tenure track faculty, sharing that tenure track faculty did not seem to care and behaved in ways that were detrimental to morale, even when the same students would speak highly of teaching track faculty.

"Our professors are highly qualified individuals, but they are not always the best at teaching. There are professors with highly regarded resumes, but I learn almost nothing from them in class or lecture.

"There are some professors here that are more research-oriented, and are not good at teaching. They still teach classes, to the detriment of students."

"There are many excellent teachers at Illinois but also several who rely on their status in the department or the quality of their research work to forgo their classes."

"The professors make people feel like they are worthless and can't achieve anything."

It is worth noting that almost all of these comments came from women, gender minorities, students of color, and international students, even those who reported high academic standing.

3.3 The quality of mentorship opportunities

Since the original study, the department made significant improvements in its undergraduate advising policies. For one, every undergraduate is now assigned a Faculty Mentor. Students are required to meet with their mentors once per year. This requirement is enforced using Spring registration holds. As published on the department's website, the Faculty Mentor's role for the undergraduate is to *"be a central point of contact and a liaison"* [20] between the student and faculty. Faculty mentors can offer assistance with choosing courses, identifying possible specializations within the curriculum, and provide information on career paths or graduate school.

Installing the infrastructure and processes to assign every undergraduate a Faculty Mentor is an important first step in developing student-faculty interactions and providing important educational and career support to students. To explore student experiences with these new infrastructure and processes, the survey asked:

(1) Why do you meet with your Faculty Mentor? (open-ended)

For this question, many students focused on the required aspect of this open-ended question. Of the 190 students who answered this question, 110 (or 57.8%) commented on how meetings with the Faculty Mentor are required and stated that this was the primary or only reason for meeting. Students wrote,

"Only because I have to, in order to register."

"To meet the requirement and check to make sure that I am on track and see where I want to go for my career."

"Honestly? Simply because it is required to register for classes."

Rather than experiencing mentoring meetings as a valuable component of their educational and career development, most students equated these meetings to bureaucratic hurdles to be overcome so they could register for classes. This could be, in part, because of how the mentoring relationship is framed - it is a requirement. Sixty percent of underrepresented minority women and over half of white men reported meeting with their faculty mentors because of this reason and, across demographic groups, this rationale for meeting was predominant.

3.4 Student sense of identity

A student's sense of identity and how that fits within the departmental culture and the larger computer science culture influences their experiences in belonging, membership, and inclusion. To investigate this component of belonging, we asked students two sets of questions.

3.4.1 Identity as a computer scientist. The first set of questions was on sense of self as computer scientist:

(1) Do you consider yourself a typical computer scientist? (Yes/No)
(2) Please explain. (open-ended)

In 2006, we found that nearly 60% of undergraduates felt as if they were not typical computer scientists, largely because of a

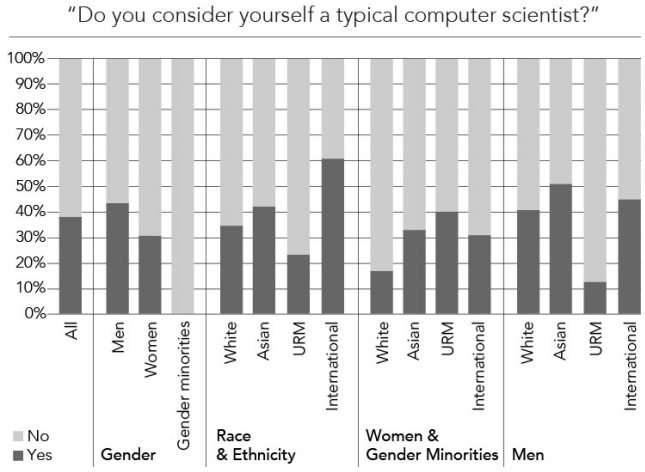

Figure 4: When asked, "Do you consider yourself a typical computer scientist", about 38% of all participants answered "Yes." Smaller proportions of women, gender minorities, and underrepresented minority students answered "Yes".

sense of isolation in the department compounded with their race, gender, lifestyle and hygiene habits, social lives, and specific area of focus within the field. In the Spring 2017 study, just over 62% of students indicated that they do not consider themselves to be typical computer scientists. As summarized in Figure 4, smaller proportions of women, gender minorities, and underrepresented minority students considered themselves typical.

Akin to the 2006 findings, frequently cited explanations for this sense of being atypical included gender, race, personal lives/lack of constantly programming and sacrificing all else, feeling like they don't fit in, not having a lifetime of programming experience before starting college, research interests, and having to work at it:

"As a woman I feel out of place a lot."

"Haha no - / I'm a female minority, I hate video games, I don't even like CS anymore because I feel [mistreated] by my department."

"I don't think computer science comes naturally to me...for others it seems like second nature."

"I consider myself atypical because I did not have programming background prior to entering college.'"

"I am more interested in theory than engineering, while the current curriculum seems to only train engineers for Google."

International students and Asian men were more likely to report that they do feel like typical computer scientists. Common reasons included conforming to stereotypes, being male, white, fitting in with others in the department, not feeling atypical, being self-taught, and having an innate ability:

"I am a male, who enjoys video games and thinks he is smart...That's how most of us are and that's why the stereotypes have developed, such as a tendency towards introversion and coffee."

"I know a lot of other people in the department very similar to me."

"I'm a white guy, I'm pretty geeky, and I taught myself to program before I had any formal introduction to computer science."

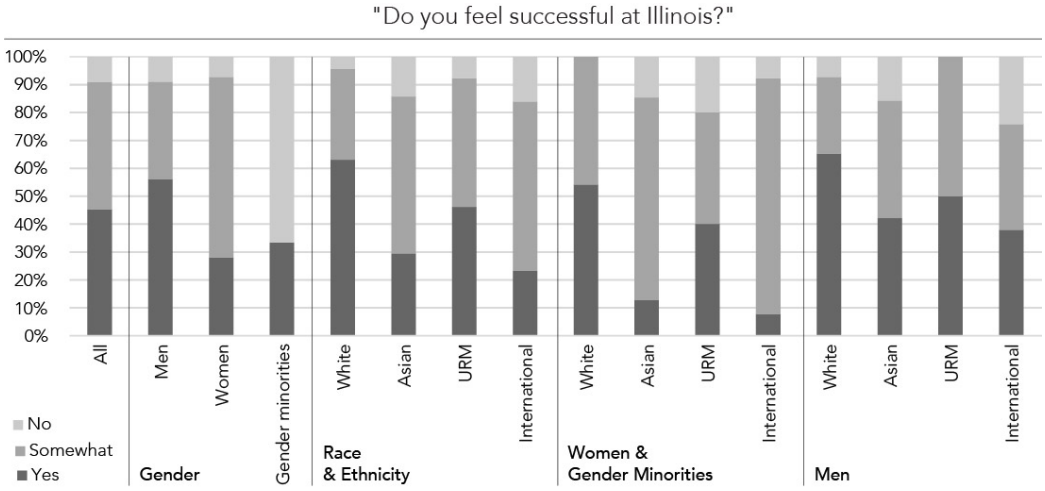

Figure 5: When asked, "Do you feel successful at Illinois?", nearly 91% of students reported feeling at least somewhat successful in 2017. Feelings of success, however, varied demographically.

3.4.2 Identity as a successful student. The second set of questions on sense of identity centered around sense and definition of success as a student:

(1) What do you consider necessary to be a successful student at the Illinois' Computer Science Department? (open-ended)
(2) Do you feel successful at Illinois? (Yes/Somewhat/No)
(3) Please explain. (open-ended)

In 2006, we found that roughly 80% of undergraduates agreed somewhat that they were as successful as their peers. In 2017, we queried them about what success means in more depth. Nearly 91% of students reported feeling at least somewhat successful. Feelings of success, however, varied demographically with white and Asian men and white women more frequently saying yes; underrepresented minority men, international and Asian women and gender minorities more likely to report somewhat; and international men and underrepresented minority women and gender minorities most likely to say no. Those who said yes were most often defining success in terms of grades, high competition internships, participation in the Registered Student Organizations (RSOs), and their own intelligence and innate ability, with the women among this group often referring to how much they've learned and what they've survived.

Among those who reported "No" and "Somewhat," they attributed this to social issues, isolation, the ease at which they see their peers doing the coursework, and expectations put forward by their peers and professors. Many women, international and underrepresented minority students called out the exclusivity of many of the RSOs and ACM in particular, referring to its culture as "toxic:"

"I don't feel like I fit in socially to the department, and constantly feel like an imposter who is just barely getting by."

"I feel incompetent seeing all my classmates land internships at high profile companies."

"I feel a surging sense of arrogance...from the community. I feel a sense of failure comparatively. Students tend to brag about how easy certain classes are despite them being difficult...Overall, it feels a little isolating."

On what it takes to succeed: "Innate ability to problem-solve, a personality conducive to competition, a high degree of focus."

"People, specially in RSOs like ACM form cliques which are not friendly/accepting to/of newcomers."

4 RECOMMENDATIONS

Overall, our follow-up study has highlighted interesting trends in the past decade. The department made progress in improving teaching through its investment in teaching-track faculty and establishing a Faculty Mentor role. However, students continue to report feelings of isolation, lack of success, abnormality, and, at times, overt hostility and ostracization in the department. Many of these problematic experiences are fueled by what appears to be a widespread belief and messages that innate talent and intelligence are required to be successful in computing. These traits create a parallel expectation that computing and the coursework should come easily, with grades and high profile internships as the primary metrics for success. Innate talent and natural ability were more often claimed by white students, largely men, while women, gender minorities, and students of color judged themselves as lacking. Much research demonstrates that the extent to which a field attributes success to innate intelligence or brilliance accurately predicts the extent to which those fields struggle with diversity and inclusion issues because women and underrepresented minority students are stereotyped as not possessing such talent [14].

Predicating success on natural brilliance not only creates dysfunctional social dynamics and potentially discriminatory evaluation processes. This is a disservice to all students. To shift this belief, departmental leadership, faculty, and staff should shift away from emphasizing talk of innate giftedness and instead focus on the importance of sustained effort, even highlighting the valuable

lessons learned from "failing" or grappling with difficult problems in their own lives [14].

In addition, the proportion of students who believe the department values teaching has slightly diminished. This is largely because undergraduate student experiences with tenure-track faculty continue to be problematic, especially for historically marginalized students. Likewise, comments from students suggest that faculty mentoring in particular is not structured or supported well; this is undoubtedly exacerbated by increasing class sizes at the undergraduate level. As bridges to computing research, educational, and role-modeling experiences, student interactions with tenure-track faculty are influential in fostering a sense of belonging, success, and future career opportunities and possibilities. That these interactions are often negative, particularly for minority groups, raises concerns about departmental and field-level retention issues.

While balancing teaching, research, and service roles as a tenure-track faculty member is no easy task, our findings indicate that additional investment in quality interactions between faculty members and students in the classroom and in mentoring relationships is an important piece of improving the departmental culture. Faculty members do not automatically know how to serve as an effective mentor or teacher. Additional professional development for faculty members in these areas combined with a matching reward structure that values these aspects of faculty work would greatly improve the culture for students and faculty. Similarly, guidance for students on how to make the most of their mentoring relationships, how these relationships can contribute to their careers, and how to engage effectively as a mentee would also help shift the attitude that mentoring is a bureaucratic task. Beyond advising and informational roles, effective mentoring relationships should also offer students educational, career, and psychosocial support and access to additional professional development opportunities and should be structured in a way that the mentor experiences value from the relationship as well [9].

5 CONCLUSIONS

Fostering a sense of belonging in computing cannot occur solely through ad-hoc methods. A suite of policies and structures must be put into place to create belonging in all aspects of departmental culture. While there have been significant departmental improvements in the past decade at the University of Illinois at Urbana-Champaign, there remain cultural, policy, and structural issues to be addressed to develop belonging and success of all students.

While we have concluded survey data collection, we are still conducting follow-up interviews and analyzing graduate student and faculty data. We plan to publish a departmental whitepaper summarizing our full results and recommendations in Fall 2018. We hope our continued work will offer additional suggestions for improving the overall departmental climate and experience. Our full survey and interview instruments are available upon request for researchers to adapt them for use in other departments.

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REFERENCES

[1] Monica Babes-Vroman, Isabel Juniewicz, Bruno Lucarelli, Nicole Fox, Thu D. Nguyen, Andrew Tjang, Georgiana Haldeman, Ashni Mehta, and Risham Chokshi. 2017. Exploring Gender Diversity in CS at a Large Public R1 Research University. In *SIGCSE*.

[2] D. Bilimoria, S. Joy, and X. Liang. 2008. Breaking barriers and creating inclusiveness: Lessons of organizational transformation to advance women faculty in academic science and engineering. *Human Resource Management* 47 (2008), 423âĂŞ441.

[3] National Science Board. 2016. *Science and engineering indicators 2016.* National Science Foundation, Arlington, VA.

[4] C. Corbett and C. Hill. 2015. Solving the equation: The variables for womenâĂŹs success in engineering and computing. *The American Association of University Women* (2015).

[5] Tanya Crenshaw, Erin Wolf Chambers, Heather Metcalf, and Umesh Thakkar. 2008. A case study of retention practices at the University of Illinois at Urbana-Champaign. In *Proceedings of the 39th SIGCSE Technical Symposium on Computer Science Education, SIGCSE 2008, Portland, OR, USA, March 12-15, 2008.* 412–416.

[6] Tanya L. Crenshaw, Erin W. Chambers, Cinda Heeren, and Heather E. Metcalf. 2017. Ten Years toward Equity: Preliminary Results from a Follow-Up Case Study of Academic Computing Culture. *Frontiers in Psychology* 8 (2017), 816. https://doi.org/10.3389/fpsyg.2017.00816

[7] Tanya L. Crenshaw, Erin W. Chambers, Heather Metcalf, and Umesh Thakkar. 2007. Recruitment, Preparation, Retention: A case study of computing culture at the University of Illinois at Urbana-Champaign. *CoRR* abs/cs/0702141 (2007).

[8] J. W. Creswell. 2008. *Research design: Qualitative, quantitative, and mixed methods approaches (3rd ed.).* Sage Publications, Inc., Thousand Oaks, CA.

[9] R. G. Hamlin and L Sage. 2011. Behavioural criteria of perceived mentoring effectiveness: An empirical study of effective and ineffective mentor and mentee behaviour within formal mentoring relationships. *Journal of European Industrial Training* 35 (2011), 7520âĂŞ778. Issue 8.

[10] Catherine Hill, Christianne Corbett, and Andresse St Rose. 2010. *Why so few? Women in Science, Technology, Engineering, and Mathematics.* ERIC.

[11] Karis Hustad. 2016. 46% of Incoming Computer Science Majors in UIUC's College of Engineering Are Women. *ChicagoInno* (25 August 2016).

[12] Lilly Irani. 2004. Understanding Gender and Confidence in CS Course Culture. *SIGCSE Bull.* 36, 1 (March 2004), 195–199. https://doi.org/10.1145/1028174.971371

[13] C. Isaac, B B. Lee, and M. Carnes. 2009. Interventions that affect gender bias in hiring: A systematic review. *Academic Medicine* 84 (2009), 1440–1446.

[14] S.J. Leslie, A. Cimpian, M. Meyer, and E. Freeland. 2015. Expectations of brilliance underlie gender distributions across academic disciplines. *Science* 347, 6219 (2015), 262–265.

[15] Jane Margolis and Allan Fisher. 2002. *Unlocking the Clubhouse: Women in Computing.* MIT Press.

[16] J. Margolis and A. Fisher. 2003. *Unlocking the clubhouse: Women in computing.* MIT press.

[17] H. E. Metcalf. 2014. Disrupting the pipeline: Critical analyses of student pathways through postsecondary STEM education. *New Directions for Institutional Research* 2013, 158 (2014), 77âĂŞ93.

[18] C. A. Moss-Racusin, J. F. Dovidio, V. L. Brescoll, M. J. Graham, and J. Handelsman. 2012. Science facultyâĂŹs subtle gender biases favor male students. In *Proceedings of the National Academy of Sciences*, Vol. 109. 16474–16479. https://doi.org/10.1073/pnas.1211286109

[19] Tia Newhall, Lisa Meeden, Andrew Danner, Ameet Soni, Frances Ruiz, and Richard Wicentowski. 2014. A Support Program for Introductory CS Courses That Improves Student Performance and Retains Students from Underrepresented Groups. In *Proceedings of the 45th ACM Technical Symposium on Computer Science Education (SIGCSE '14).* ACM, New York, NY, USA, 433–438. https://doi.org/10.1145/2538862.2538923

[20] Department of Computer Science. [n. d.]. Undergraduate Advising. ([n. d.]).

[21] Katie Redmond, Sarah Evans, and Mehran Sahami. 2013. A Large-scale Quantitative Study of Women in Computer Science at Stanford University. In *Proceeding of the 44th ACM Technical Symposium on Computer Science Education (SIGCSE '13).* ACM, New York, NY, USA, 439–444. https://doi.org/10.1145/2445196.2445326

[22] RHIT. 2016. Record-Breaking Freshman Class of Female Students Expected for 2016-17. *http://www.rose-hulman.edu/news/academics/2016/record-breaking-freshman-class-of-female-students-expected-for-2016-17.aspx* (May 2016).

[23] Rob A. Rutenbar. 2016. Letter of support for National Science Foundation Grant proposal submitted by the authors to SCIENCE, TECH & SOCIETY on 02/02/2016. (January 2016).

[24] Terri Williams. 2016. Women Total 48.5% of Carnegie MellonâĂŹs 2016 Computer Science Class. *Good Call* (26 October 2016).