Broadening Participation in Computing: Issues and Challenges

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ABSTRACT
In this paper we survey the literature to identify the issues and challenges of broadening participation in computer science, and provide some suggestions to address these challenges. Our attention focuses on redefining the way we approach computing education so that we can successfully entice students to computing that have not traditionally participated, thereby promoting diversity and increasing the total numbers of computing professionals. Based on the literature review, we propose an *interactional* model from the social sciences to inform the way in which we might restructure and broaden the definition of computing and provide some examples of strategies that we have found to be successful in practice.

Categories and Subject Descriptors
K.3.0 [**Computing Milieux**]: Computers and Education- *General.*

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1. INTRODUCTION
While the lack of diversity in the computing disciplines is alarming to computer scientists, there are reasons for others to be concerned. Software products are pervasive and are becoming an indispensable part of most modern activities and enterprises.
Software that is developed by uniform groups reflects the particular cultural biases of the groups and not necessarily the groups of society being served. These differences can render products that are unappealing and not as useful to a large portion of society. In contrast, when diverse groups solve problems, the different perspectives that emerge are more likely to yield widely applicable solutions to the most pressing problems. Therefore it is beneficial to society at large that we broaden participation in computer science by finding effective strategies to recruit and retain students from groups that are underrepresented in the field.

Another problem faced in the US that may be solved by broadening interest in computer science is the trend of declining enrollments in college computing programs that has industry and institutions of higher education worried. The US Labor Department projects that job prospects are strong for students graduating from computing programs, but students are not joining or staying in the numbers needed at all levels. (http://www.cra.org/CRN/articles/nov06/vegso.html). Some speculate that computer science departments and programs must reinvent the way they train students if they wish to attract and retain the next generation of technical workers. In short, we believe we must not only increase our numbers, we must do so in a way that reflects the diversity of our society.

While it is clear to labor and computing experts that the declining numbers of computing professionals is a problem, students, parents and public school professionals are still not informed of the opportunities for students who might major in these disciplines. For example, the bursting of the dot-com bubble and the outsourcing of computing jobs has led public schools and parents to discourage many aspiring computing majors. Needed is a means of communicating to the general public the growing dependency of the US on innovation and the ability to compete internationally in the technical arena. In the past, we have become dependent upon immigrants willing to pursue technical majors at the highest educational levels; many graduate programs in the computing disciplines have a large percentage of students from Asia. However, these enrollments are also declining. Thus, we must pay special attention to developing talent internally and to communicate this need to our own citizenry.

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Researchers have speculated that if we attract talented women and minorities to the computing disciplines, we will be able to significantly increase enrollments and provide a highly talented group to the workforce in the US [17]. At present, women make up a small percentage of the graduating computing majors, whereas they now represent slightly over 50% of the students currently enrolled in higher education institutions.

An array of initiatives to increase the numbers of women and minorities in Computer Science (CS) are being implemented nationwide. They have a wide variety of foci, including, but not limited to: active recruitment [7] curricula changes [27, 28] mentoring and role model programs [7,11,14,18] academic culture change [2,6] and interventions with younger students to combat stereotypes [20, 2003,24]

While laudable in their efforts, many initiatives could be augmented by a more conscious awareness of psychosocial factors that serve to undermine their efficacy. Programs targeted at changing individual perceptions, such as those providing strong role models and actively promoting computer science as attractive to underrepresented groups, as well as those targeting institutional barriers with, for example, curricular changes and formal mentoring programs, are necessary but not sufficient in both recruiting and retaining females and minorities in CS.

Here we explore a three tier theoretical model from the social sciences to explain how we might increase the numbers in computing programs through interaction. We provide the model and show examples for execution of its principles.

2. THE ISSUES AND PROBLEMS

Experts have speculated on how the image of computing and the climate in computing programs may be deterring students from entering and staying enrolled.

2.1 The image of computing

Research suggests that there is a strong association between masculinity and computers [3,12,,16,26]. Software and computer clubs are perceived as being male oriented and computer games that feature violence, militarism, and sexualized images purvey sex-role stereotypes.

Computer science is also perceived as having no creativity, or interpersonal or social relevance [28], which also functions to discourage women from considering the field. The end result is that girls enter college with little motivation to study computer science. Increased identification with the field at an early age is key in the recruitment of students, and requires an innovative communication and marketing campaign.

2.2 Climate for underrepresented groups

The research of Claude Steele and his colleagues (e.g., [34,35]) indicates that underrepresented groups experience a stereotype threat from being one of a very few in their subgroup and outnumbered by a larger group. Studies indicate that when individuals are placed in a situation where they are underrepresented, and prevailing stereotypes predict that individuals from their group of identification will not perform as well as those in the majority group, then their performance is eroded. The stereotype becomes a self-fulfilling prophecy. Underrepresented groups in computer science such as women, people of color and those who are the first to attend college are stereotyped as having less interest and identification with the field. This works to inhibit participation and performance, particularly with the current preponderance of white males in CS. Thus, a stereotype threat can have a profound effect on even well meaning recruitment and retention efforts.

Early research [12,32] made clear the fact that classroom teachers tend to pay less attention to girls than boys and behave in ways that indirectly diminish the potential of female students. Though more subtle, these dynamics are still at play in today's classrooms. As the American Association of University Women's Technology Commission notes, computer science classes are often "bastions of poor pedagogy" [3,23]. Despite awareness and education about more gender equitable teaching practices, a chilly climate for women in computing classes may exist because how teachers continue to "do gender" [39] as they interact with students remains invisible. From a social science perspective, "gender" is not a biological sex category, but rather is how we conduct ourselves in a social environment as males and females according to accepted cultural norms, and, as such, is a construct that defines, and is defined by, social interaction. What is missing from this analysis is a rigorous effort to match positive attitudes and good intentions with actual (what we will call *interactional*) practices that do not subtly reflect traditional assumptions about women and minorities, and computer science.

For example, in a National Science Foundation ADVANCE program at the University of Rhode Island (URI), we assessed individuals' readiness to embrace and engage in change to promote the careers of women faculty in science through a campus-wide survey of 277 faculty. The survey results were surprising. Of the 135 science, technology, engineering, and mathematics (STEM) faculty who responded to the survey, nearly 80% reported that they were already engaged in several key behaviors that support the careers of women faculty. These results conflicted with anecdotal reports and our own observations of chilly work environments and inequitable distribution of resources in many of the departments. We became aware that individual explicit perceptions and intentions can be in contradiction to actual subtle practices in departmental interactions that implicitly reinforce traditional gender roles. We guess that this is also the situation in the classroom with teachers who are interacting with students. Thus, our efforts, especially in climate workshops with faculty, are now informed by understanding that systemic change is possible only when interventions are targeted at multiple levels — individual, institutional, and *interactional* [31].

3. THREE TIER MODEL

Research suggests that gender and class are not only a part of individual identity, but also principles of social organization and social interaction. Thus, social and institutional policies, on the one hand, and individual intentions, on the other hand, as positive as they may be, are ineffective if they occur in a context that is defined by traditional expectations about class and gender [1,4,8,9,19,29,30,31]. In essence, real change cannot be achieved unless the cultural expectations about class, race, ethnicity, and gender that guide interaction are confronted and changed, along with social and institutional barriers, and individual perceptions. Most organizational change efforts to date have had two foci – an emphasis on top-down or structural change, and an emphasis on bottom-up, individual change. However, focusing on a third interactional level highlights the subtle contradictions that occur in the normative practices of individuals with good intentions and supportive beliefs. That is, the link between individual motivations and social and institutional policies is upheld by individuals “doing gender” (or “doing class” or “doing race”, etc.) routinely through interaction.

Gender and class categories make it easy to facilitate social interaction; we know what to do and how to act. The problems occur when students step out of their usual habitats and enter into an environment in which they are not normally found. Stereotype threat is but one example of the impact that this may have upon students. More overt behaviors have been anecdotally observed among our students. For example, male students warning female students that they will probably leave the computer science program because most other females have, and a parent declining to send their young daughter to summer computer camp because they can’t imagine her developing a career in which she will be interacting with a computer the rest of her life.

4. THE *INTERACTIONAL* LEVEL OF ENGAGEMENT

It is tempting to look at the stereotypes associated with computers and the negative outlook for tech jobs, and see these influences as the simple reasons why women and students from minority groups shun computer science programs. The evidence for these effects is apparent and well researched. They also indemnify us as educators since they cannot be greatly controlled or influenced from within our schools and classrooms as we cannot compete with the news and entertainment media at large. Therefore the questions for us within the context of the classroom should be what can we do within each level of the school system and can we influence what occurs outside of our school gates? We need to pay attention to the climate and the image of computing at an interactional level. Therefore we offer some examples from experience to remedy the problems of recruitment and retention using Risman’s model to pay attention to specific interactions with students, their families, and their teachers at all levels of the pipeline.

Traditional teaching approaches focus on abstract learning. It has long been suggested that putting more emphasis on applied contexts, interpersonal or social relevance, hands-on research, multidisciplinary team approaches, collaborative learning environments, and problem-solving applications results in greater interest and retention of women and minorities within the sciences [15,33,37,38]. Specifically, [16] demonstrates that students are more motivated and have less negative attitudes towards tailored, contextual, application-based computer science courses, leading to more engagement and interest and less anxiety.

To focus more on context and application, we suggest interdisciplinary studies in problem domains of clear benefit to society as a path to introduce computer science to a broader cross-section of students. When developing an interdisciplinary program, it is important to take into account the different goals, value systems, and learning styles of the target population of students. Policies that promote student and curricular diversity (institutional level response) and instructors who welcome women into their classrooms (individual level response) can be sabotaged when actual classroom practices are more relevant to male students. If the same computer science courses are taught, but in contexts that are relevant to specific student groups, the interactional level that we are suggesting is so important can be attended to. Research indicates that curricula that respond to the different learning styles and aptitudes of a diverse student population will do much toward increasing retention of under-represented groups [27,28].

Example 1: As we have witnessed at our institution with programs in digital forensics (http://forensics.cs.uri.edu), bioinformatics (http://bioinformatics.cs.uri.edu/), and at IMEDIA with new media (http://www.imedia-academy.org), and in 3D graphics (http://3dgroup.cs.uri.edu/), interdisciplinary studies circumvent the stereotypical thinking many students have about computer science. Other examples under development are cryptology courses, eco-informatics, and digital libraries. Interdisciplinary programs seek to blend technology into another discipline with a high degree of application orientation. The literature indicates that students from underrepresented groups are as attracted to problem solving as are students already in computing programs, particularly if they can see the application to society [21,22,5].

Example 2: The International Certificate Program for New Media (ICPNM) at IMEDIA involved a combination of instruction and hands-on experience in the science, technology, creative practices, and business processes of new media [13]. The early to mid career professionals who participated in this program came from a range of different cultural, educational, and occupational backgrounds, including art, design, architecture, English literature, computer science, engineering, biology, economics, and philosophy. They had more than a dozen cultural origins and they spoke as many languages natively. There were roughly equal numbers of men and women. To accommodate the needs of these students, the program focused on the application of technologies supported by their theoretical foundations. We employed innovative design- and group-based teaching practices, coupling students with technical and nontechnical backgrounds. We paid special attention to mentoring each student in a project that was well matched with their own interests and career development path. Due to this approach, the response of nontechnical students to the technology-based sections of the curriculum was positive. Nontechnical students have routinely undertaken and excelled in practicum projects involving significant technical content even though many of them suggested from the outset that they did not have interest in the technological basis of new media but mainly wanted to learn how to use the tools.

Example 3: For the past three years, we have been running a Research Experience for Undergraduates (REU) Site sponsored by the National Science Foundation to encourage student retention in computer science, particularly undergraduate computer science and art students moving into graduate programs and scientific careers. Thus far, we have recruited 27 students, and eight have traveled to Germany as a part of the international component of the program in which they engage in a research project at a lab within the INI-Graphics Network (http://www.ini-graphics.net).

We did not assume that students would enter the program with knowledge of or experience in interdisciplinary research. Instead, we paid special attention to training for collaborative work, receiving mentoring, problem solving, international issues, ethics, etc. This was carried out through a seminar series in which we also aimed to develop collegiality within the student research group. We also permitted the students to choose among a variety of settings, research groups and mentors to assure there was connection between their own academic and career goals and the research they were carrying out.

Students reported that they valued the interdisciplinary and international experiences. Some students who had previously not considered research as a career returned to graduate programs in computer science, and a number of students from art and design background furthered their studies in computer science. Further details and results of the program are reported in [25,36]. Educators have also used computer graphics research with good effect to retain computer science students at another critical juncture between the first and second year where many students are lost [10]. We speculate this is so because of the clear and visual connection to applications of interest to the students.

Other practices that attend to the interactional level of the learning context include:

- instructors who use materials and examples that are inclusive to underrepresented groups
- informal groups of students formed outside of formal learning
- experiences that are welcoming and relevant to women and students in other underrepresented groups. (moving from UNIX install fests for student groups to a tutorial on the use of forensics or bioinformatics software tools.)
- biographical sketches of successful computing professionals from underrepresented groups on department websites to show students and their families that they are welcomed and belong in computing.

These underrecognized "incidentals" to actual learning might make students feel both interested and "at home" in a major.

Regardless of what we do in the classroom to retain students, many turn away from science and computer science well before they have started to consider their college careers. While interdisciplinary studies should offer an attractive option to many students, students have to understand their options. A campaign that informs students of the breadth of the computing disciplines to include information systems, management information systems, computer engineering is also necessary. This must take place in the public schools on the elementary, middle school and high school levels. Parents, students and advisors must be informed about the nature of computing and the benefits to participants and eventually society via a robust and inclusive marketing program. The subtle though powerful messages that interactional components offer need to be brought to bear in this program. Embedded and invisible cultural norms that "gender" and "culturally" define the computer science discipline need to be unveiled, and replaced with a conscious attention to practices that may contradict stated inclusion goals. Promoting women and minority role models, including these students as project leaders and peer mentors, emphasizing social connections in the classroom, as well as societal relevance throughout the curriculum provide a few examples. We urge all who plan to address the issues of broadening participation in computing do so with an eye to increasing the numbers, broadening the definition of the discipline, and proceeding with a strong *interactional* plan.

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