Promoting Diversity-Inclusive Computer Science Pedagogies: A Multidimensional Perspective

Vahab Pournaghshband
Computer Science Department
University of San Francisco
vahab.p@usfca.edu

Paola Medel
Gender Studies Department
University of California, Los Angeles
paoladmedel@gmail.com

ABSTRACT

The field of Computer Science has long been criticized for its lack of minority representation. While extensive literature documents possible causes and solutions to promote diversity, CS still falls considerably short of other STEM disciplines. Through an interdisciplinary approach, we urge that a multidimensional perspective be applied to develop and assess pedagogical strategies aimed at improving student diversity. To the best of our knowledge, our paper is the first that, in the context of CS, (1) examines the need to adopt an intersectional approach in more than just two dimensions, and (2) defines and identifies the *Fallacious Archetype* of a successful CS student. Also, we are the first to investigate the possibility and implication of examining certain other minority types: gender non-binary students and age-related student minorities. To conclude, we provide contextual examples that take an intersectional approach to assess CS diversity-inclusive pedagogies.

CCS CONCEPTS

• Social and professional topics → Computer science education;

KEYWORDS

Diversity, Gender, Race, Socioeconomic Status, Age

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1 INTRODUCTION

Currently, Computer Science Education research on increasing minority representation has been mostly limited to two factors: (1) Enhancing female participation, and (2) promoting racial diversity. The former is well researched, with extensive literature documenting causes of underrepresentation and proposed solutions [6, 9, 25, 26, 31, 33, 38, 39]. Literature on increasing racial diversity is also a developing area [21].

While these single-faceted examinations of two elements[1] have proven to be valuable, they are not complete. We believe that the existing approaches are limited in capturing the interrelationship that may exist between social identity elements. A more effective approach should go beyond examining these independently, and examines them as "reciprocally constructed phenomena [28]." In the Social Sciences, this is referred to as *intersectionality* [8, 28]. Only very few studies, in CS, have examined how the intersection of two (e.g., gender and race) may produce varying data, compared to merely examining them as mutually independent factors [27, 35, 40]. Varma [40] demonstrates, when considering women, socioeconomics status (parental occupation, education, and income) accounts for a substantial amount of the differences in exposure to IT. Scott et al. [35] discusses the intersection of gender and race by examining the experiences of "girls of color." Their finding demonstrated that within-race gender differences exist in early interest in computing. They argue that the observed lower engagements and interest in computing suggest that being a member of a marginalized gender group has a multiplying negative effect. Additionally, Mellstrom [27] argued for cross-cultural work and intersectional understanding. The author used Malaysia as an example to support the core argument that gender and culture must be examined together. This is because in Malaysia, the "woman problem" [22] is non-existent since women's education and their positions in computer science departments and software employment are equivalent to those of men [27].

This paper addresses and examines the need to adopt a multidimentsional intersectional approach in the context of CS, beyond examining merely two elements. We demonstrate that to develop and assess pedagogical approaches aimed at promoting diversity, we must adopt a multidimensional perspective of student identities beyond only gender and race. Furthermore, we elaborate on the need to not only examine more dimensions, but also investigate the intersections between them. We use an interdisciplinary approach that views students as having intersectional identities, not limited to only single-faceted identities. The focus of our paper is on four main elements that form social identities: gender, race, socioeconomic class, and age.

While examining these four social identity elements, we also show that students who match the hegemonic profiles of 'successful' CS students tend to possess certain values for each component. Those are: male gender, white race, middle or higher socioeconomic

[1]Social identity elements are comprised of many components, including gender, race, socioeconomic status, and age.

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status and young age. We define this combination of values for each categorical variable as the *fallacious archetype* of what constitutes a successful CS student.[2] This finding is particularly significant, because existing research on gender inequality shows that when minorities do not fit into an archetype, they tend to have lower self-confidence in computing abilities [6, 25, 38]. Likewise, low confidence is associated with decreased performance [6].

To illustrate the feasibility of applying a multidimensional approach, we use examples of our ongoing work on promoting CS student diversity, through the intersectionality perspective. These examples show how CS education diversity researchers can incorporate a multidimensional approach to data collection and analysis.

In the next Section, we present the four elements critical to examining CS student identities.

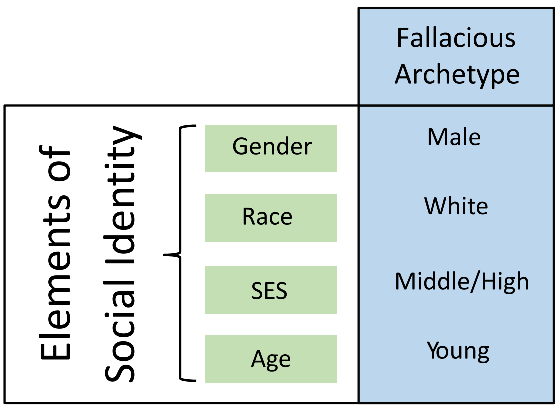

Figure 1: Illustration of the Four Elements of Social Identity; Profile of the Fallacious Archetype.

2 ELEMENTS OF INTERSECTIONAL IDENTITY

We demonstrate the four elements of intersectional identity through four Sections (Figure 1). Each Section first discusses why and how that element attributes to a marginalized CS student profile through literature review. In addition, we demonstrate some features of inequality and marginalization never before explicitly addressed in CS Education: non-binary gendered students, the role of students' socioeconomic status, and their age. Finally, each Section includes an analysis on how that element creates a dimension of the fallacious archetype of a successful CS student.

2.1 Gender

This Section provides an overview of some well-researched and known issues of gender inequality in CS. Notably, we investigate a source of gender inequality previously disregarded in CS: the gender binary. We discuss the need to adopt a non-binary approach to CS diversity initiatives. Finally, the gendered element of the fallacious archetype of a successful CS student is identified.

[2]It is important to note that we distinguish fallacious archetype from stereotype.

2.1.1 Binary Gender Inequality. Manifestations of gender inequalities in CS have long been well-documented [2, 3, 5, 6, 23, 25, 26]. These exist in the CS industry, undergraduate and graduate levels of education, as well as in academia [6]. Although women's performance indicators show figures competitive to men's, studies consistently show that their confidence levels are considerably lower than their male counterparts [7, 14, 16]. This has been attributed to factors such as perceptions of a masculine environment [6, 26], unequal treatment by faculty [6], and inequalities in course materials [26].

The male-dominated CS course culture is described in a study [16] in which a cohort of students overwhelmingly responded that the top students were "hardcore" and described hardcore as an exclusively masculine domain [16]. This finding is consistent with other studies of gender in CS [3, 9, 26] which imply the existence of an established social hierarchy within CS course culture that assumes males are the most successful students, thereby creating a glass ceiling effect on women. Also, stereotypes within the course culture have been shown to question women's intellectual merits. For example, Cohoon [6] found that women experienced significantly lower levels of confidence in CS departments where faculty hold beliefs that diversity lowers student quality [6]. Finally, male-oriented course materials also suggest that CS is a masculine domain [26]. For example, Medel and Pournaghshband [26] demonstrate that the image of Lena originally taken from Playboy Magazine, commonly used in Image Processing and related fields, severely objectifies women. This, in turn, creates a male-dominated environment that mitigates women's performance [26].

2.1.2 Non-Binary Gender Inequality. Gender scholars have argued that although most people do fall into the categories of male/female, this binary fails to encompass all people [4]. They also show that gender is a social construction, not a biological certainty. In fact, gender refers to feminine and masculine behaviors/identities, as opposed to biologically innate qualities. Gender for some, is also a fluid, rather than static quality of their identity [4]. As a result of increased gender awareness, the amount of people identifying with non-binary genders has doubled in the last five years, in an American study [15]. Most of these people are of traditional college-age (18-24) [15]. Bilodeau [4] argues that gender equality is dependent upon framing research to break strict gender binaries. Hence, when evaluating pedagogies and their effectiveness in promoting gender minority representation in CS, we cannot merely categorize students into a male/female binary. Rather, we must consider students' own reflections of self-identity.

2.1.3 The Fallacious Archetype: Male. As a result of the long history of male-dominance in CS culture, the fallacious archetype of a successful CS student is clearly male. Since CS has long faced a shortage of women, it is unsurprising that the culture projects maleness as an idealized image. To compare, women have been associated with stereotypes, such as the example of harmful imagery [26], and lack of intellectual merit [6]. Hence, the first and most clear attribute of the fallacious archetype of a successful CS student is that he is a man.

2.2 Race

In this Section,[3] we discuss how racial and ethnic minority students (REM) may face certain social barriers compared to their White counterparts, and the implications of those disadvantages. We then examine how race is a variable that forms the fallacious archetype of a 'successful' computer science student.

2.2.1 Preparation Inequality. Despite parallel or heightened interest and confidence levels in the desire and ability to learn CS, REM students encounter 'structural barriers' that may prevent them from accessing CS learning opportunities [36]. An extensive study conducted by Google and Gallup [36] shows that Black students are less likely than White students to have classes dedicated to teaching CS at school. Also, Black and Hispanic students are less likely than White students to use a computer daily at home [36]. This is notable, since comfort using and playing with computers is cited as a confidence predicting variable for CS students [3]. Since pre-college preparation is a known factor that influences student performance in CS [3], we consider these barriers critical to REM students' perceptions of belonging in the discipline.

2.2.2 Accessibility Inequality. Generally, Blacks and Hispanics are less likely to have exposure to CS than their White counterparts [36]. Exposure to CS is well documented as an important factor for involving more minorities in the field [39]. Hispanic students are less likely than Black or White students to have home access to a computer [36]. Also, they are less likely than Black or White students to have a computing adult role model in their lives [36]. Katz et al. [18] shows that Hispanic students in particular, benefit from mentoring to provide them with the cultural congruence necessary for STEM success.

2.2.3 Achievement Inequality. A comparative study on stratified racial achievement in CS revealed that, in all areas but one, Black students scored lower than their White/Asian counterparts [18]. Black students also took longer to work through their assignments than the non-minority students [18]. Notably, the study controlled for background variables such as access to computers and the Internet. This suggests that further investigation should be done to understand this incident, such an through an intersectional perspective.

2.2.4 The Fallacious Archetype: White.
a) Industry Profiles

The CS industry is staffed with predominantly White and Asian men, with White men constituting the majority [36, 42]. Therefore, we identified whiteness as the racial value in the fallacious archetype of a CS student.

Although tech companies commonly refer to a lack of available racially diverse candidates, graduate rates of REM students compared to the percentage of REM new hires is discouraging. In fact, although Hispanic and Black students accounted for approximately 6% of CS graduates in 2013, only 2% of tech hires are Black, and 3% Hispanic [42]. This illustrates the severe disparity in racial representation in the CS industry.

b) Media Profiles

Like the industry, the media seems to project racially stratified bias of the CS archetype. As such, Hispanic students are less likely to report seeing 'people like them' performing CS in the media [36]. This suggests that they have less perception of their potential to fit into the dominant norm what a CS worker looks like [36]. This is critical because CS studies on increasing minority confidence show that identifying with the dominant culture of a field is critical to establishing student confidence [6, 16, 25, 38]. Media is a form of establishing dominance in a given realm, like CS, and can be a powerful force in breaking and/or establishing dominance.

c) University Profiles

Racial stratification is not limited to the media and industry, but is even more apparent in educational settings. For example, although students of color constitute 49% of the high school student population, they are only 9% of total AP Computer Science test takers [44].

In a study on Latino students in STEM, Rankin and Reason [18] found the REM students experience more stereotyping, racial prejudice, and unfair treatment from faculty members, teaching assistants, and peers. We argue that this may be the result of REM student's profile not fitting the hegemonic norm of 'whiteness' in the field of CS.

2.3 Socioeconomic Status

In this Section, we discuss how low Socioeconomic Status (SES) students face increased challenges to enter and perform well in the field of CS. To our knowledge, students from low SES backgrounds have been largely overlooked in studies aimed to increase minority student involvement in CS. Nevertheless, prior STEM studies suggest that SES plays a greater factor than gender or race in predicting success [41]. Thus, we consider aspects of STEM studies on low SES students that may be particularly relevant for CS Education.

2.3.1 Opportunity Inequality. Low SES students tend to face disadvantages compared to their middle class and higher counterparts prior to college enrollment. These inequalities pose a threat to the success rate of such students. We argue that these inequalities are particularly critical in low SES students' potential to enter and thrive in the CS field.

Low SES is linked to less access to experienced teachers and school resources [10]. This is critically true regarding higher level mathematics and science instruction [10] which may discourage student comfort in selecting a scientific discipline in college [10]. We argue that this affects such students from entering and succeeding in CS in particular because CS is not an established component of core k-12 curriculum. Rather, CS courses in k-12 are more likely to be found in schools with greater resource access. In fact, school administrators regard a lack of experienced teachers as the greatest barrier to providing CS education [36]. Schools serving in areas of low SES background may face even greater challenges in finding suitable instructors [10, 36]. Since prior exposure to CS is a well documented factor in predicting student achievement in college CS, we emphasize the importance of considering student's SES to promote diversity in the field.

2.3.2 Expectation Inequality. Students from low SES backgrounds differ from their more privileged counterparts in terms of family

[3]Due to a lack of sufficient literature on races outside Black and Hispanic, we focus on these groups as representations of racial inequalities that exist in CS educational structures. See Section 4 for further discussion.

interactions [29]. This includes the expectations families have on students, which tends to reflect prior performance [29]. This can be harmful to students due to variance in family's recollection of the student's success and incongruence with their actual potential [19]. This, combined with low SES student access to high quality learning resources, can create a social barrier preventing them from gaining the necessary confidence to consider the field of CS. Expectations are also influenced by low SES family's ability to provide educational resources [17]. This ability is linked to financial resources, creating a harmful cycle that inevitably leads to low expectations for the least privileged of low SES students [17]. Studies on female confidence in CS have documented expectations as a factor influencing performance [6]. Lower confidence is associated with decreased performance [6]. Hence, we stress the significance that SES can have on minority student's futures in CS.

2.3.3 Fallacious Archetype: Upper/Middle Socioeconomic Status. Due to the aforementioned factors of inequality detracting students from low SES backgrounds from entering the field of CS, we argue that SES it is a critical component of the fallacious archetype of a CS student. Although it is unique in relation to the other, visible components of the archetype, it is present nonetheless. Our inability to see with the naked eye, a classroom of CS students and profile each of them into a distinctive SES level is what distinguishes SES from the other factors we discuss: gender, age, and race. Perhaps this is why prior studies on underrepresented minorities in CS have almost completely overlooked this crucial trait. Nevertheless, it holds considerable weight in the strive for minority inclusion. In fact, when a study controlled the factor of SES, the performance gap between black and white students was statistically insignificant [41]. We further validate our argument through a study on women in CS [9]. In this study, the participants reported that, despite their (female) minority status, their confidence in computing ability was fostered by financial support from their families. Hence, we see that there exists an underlying constant of financial support behind the archetype of a confident CS student.

2.4 Age

2.4.1 Industry Inequality. Agism is the most accepted form of prejudice and is often overlooked [1]. Nevertheless, literature documents ongoing age discrimination within the industry. In fact, the computer industry is well documented as being one of the most ageist fields [13, 20, 43]. Xia and Kleiner [43] describe the issue of ageism in the 'youth oriented industry,' explaining that older individuals are falsely regarded as 'dinosaurs'. Hence, CS professionals perceived as old are marginalized and punished. Such discrimination often leads to legal action against tech companies such as Intel, which had 90,000 age discrimination complaints filed within one year [43]. Facebook, Electronic Arts, and Yahoo have faced similar scrutiny in recent years [20]. Young people are described as being more intelligent (than older people), even publicly, by known executive figures [20] while older CS workers are considered outdated in terms of knowledge and ideas [20, 43]. Also, companies may discriminate against hiring older workers due to the monetary incentives associated with hiring younger people; lower salaries are justified by less experience. Interestingly, although younger people do make lower salaries than older and more experienced employees, the relationship between age and experience does not indicate fair levels. Older employees do not earn as much as younger workers with the same amount of experience, in CS [12].

Since the field is saturated with young workers, managerial positions are usually given to young people. In turn, they are unlikely to hire older employees due to discomfort working with and giving orders to an employee older than themselves [43]. This creates a vicious cycle that leads to further alienation of older CS professionals.

2.4.2 Education Inequality. It is particularly crucial that CS educators recognize and address the element of age as a vital component of an intersectional student identity. There is an influx of older people returning to school to compete in today's highly competitive workforce [30]. CS is particularly attractive to people returning to school for a second degree/career change due its large and growing employment opportunities [12]. However, older adults may be at increased risk of failing [30]. Many adult learners face heightened challenges not present for their younger counterparts. This includes access to information such as program length, post-graduate employment opportunities, financial aid opportunities, and child-care options [30].

2.4.3 The Fallacious Archetype: Young. Higher education systems are built primarily for traditional (young) students [30]. As such, students who do not fit this archetype are already marginalized in university settings. This is emphasized much more in CS, since the dominant CS culture dictates young people's ideas as fresh and old people's ideas as outdated [43]. This archetype becomes apparent when we examine the absence of older perspectives in technology.

There is a need to adapt older perspectives into CS developments. As technological solutions because available, they enter the lives of not just those who seek them, but all people. In an example setting, medical technology is specifically critical for older generations whose health may benefit or even depend upon it. However, because the standards of hegemonic normativity largely limit developers to young people, even technology targeted for older people reflects young perspectives. As such, interface designs do not consider the needs of older users [34]. Elderly people have unique needs that must be met in order for them to effectively use technology [34]. As such, it is necessary to incorporate age-appropriate values into interface designs to increase usability of devices for aging users.

3 INTERSECTIONALITY

Students naturally have varied experiences in a field based on a variety of factors. For instance, not all females have the same experiences as each other, and should therefore not be categorized into the same 'box.' Similarly, not all Hispanic students face the same challenges or have the same opinions as their Hispanic peers. Factors such as socioeconomic status can create drastically different perspectives for a wealthy Latino male whose parents had college education, than a Latino male from a lower socioeconomic class whose parents were not college educated. Therefore, we must examine a web created by the combination of these four forces that, depending on the values given by each force, produces highly varying realities for each individual. This multidimensional perspective is widely used and accepted in the social sciences and referred to as intersectionality [8].

Examining pedagogies through an intersectional perspective could lead to finding relationships and correlations between different dimensions. For example, in a study in STEM, Watson [41] found that in the presence of controlling SES, race was insignificant in distinguishing performance between Black and White students. Also, women of childbearing age face a double barrier in obtaining employment in the computer industry [42]. While women receiving degrees in CS account for a mere 18.2%, that figure drops four-fold for women of color to 4.8% [11]. Thus, it's clear that when intersecting gender and race, we can draw more insightful conclusions than through a singular perspective approach. We envision that future studies could derive relationships and correlations between these dimensions to model the interrelationships and significance of each factor in the presence of others (e.g., using probabilistic graphical models).

Failure to consider intersectional identities may lead to false unification of a cohort's variability of experiences. Prominent scholars of Gender Studies have long shown that neglecting or disregarding intersectional identities for women, particularly in STEM [37], oppresses women of color by disregarding their experiences [24], by creating the false perception that all women are uniform [24, 37]. In fact, even in efforts designed to promote the inclusion of women in STEM, a study [37] shows that by disregarding the intersection of race with gender, women of color are being oppressed through the National Science Foundation's ADVANCE program. Hence, CS education researchers must incorporate intersectionality in their inclusive approaches and pedagogical assessment methodologies.

We have demonstrated in Sections 2.3 and 2.4 that age and SES are notable variables in CS student equality. Thus, involving these elements of intersectional identity into the multidimensional perspective is also imperative for future inclusive pedagogies and assessments. Through the same reasoning provided by Lorde [24] and Torres [37], to not consider these elements would actually oppress students affected by them.

4 DISCUSSIONS

While this paper focuses on select crucial elements of students' intersectional identity, we note that future studies could examine other aspects as well. Such may include geographic location, able-bodiedness, cultural variations, sexual orientation, and linguistic background. Student's home background, such as geographic location, may impact the types of adversity they face. For example, those coming from from rural areas may have less access to technology. The variables attributing minority status to individuals is also highly variable by culture, and must be studied independently. For example, a recent Google study on CS Education in Spain [36] revealed barriers unique to that country that do not exist in American context. Able-bodiedness (as opposed to dis-ability) could also play a considerable role in forming students' multidimensional identities. Investigating both mental and physical forms of able-bodiedness may provide insight in the factors that contribute to inequality in CS education.

To provide the first advocacy of the need to incorporate a multi-dimensional perspective to evaluating student's backgrounds for pedagogies, we use largely studies from North American students. Within this context, we focus on studies conducted on Hispanic/Black minority students, due to the prevalence of people from these races in our society. Nevertheless, we believe that our work can be applied to other countries/cultures as well as other minorities in North America such as Native Americans and Pacific Islanders, to improve minority students' representation. The same four elements we discuss can be used, as well as a combination of others such as religion, social class, or linguistic background, as needed.

5 A MULTIDIMENSIONAL ASSESSMENT APPROACH

At our institution, California State University, Northridge, we have developed a diversity enhancement program. Our university is a large, public, primarily undergraduate, minority-serving institution in North America. The primary objective of this program is to increase minority student participation and enhance their performance. This includes racial, SES (or low-income), and gender minorities.

This program promotes activities that foster close interactions between students and faculty. One such interaction is consistent, individualized meetings designed to monitor student academic progress and provide academic/career advising. Further interaction is given through student involvement in research projects to encourage them to stay connected with their majors. Research shows that Hispanic students, in particular, benefit from this type of positive faculty interaction, leading to increased retention [32]. Similarly, peer mentoring is offered. This provides immersion in a relatable group of peers leading to a sense of belonging. This increases students' self-confidence. The literature supports this type of support, demonstrating that racial and ethnic minority students' retention is enhanced through peer networks within their same discipline [32].

In addition to recording retention, graduation rate, academic and post-graduation success, we also are collecting individuals' perceptions of the effectiveness faculty interaction as well as student-peer interactions, and their own self-confidence. These data have been collected through a series of pre/post-tests, journals, and interviews.

In order to assess the success or effectiveness of our program, we refrained from using the traditional, one dimensional perspective to identifying students. Rather, we used a modified (intersectional) approach to collect student background data and conduct post-program data analysis. Below we show an example of each that we have incorporated:

a) A More Inclusive Approach to Data Collection

We propose a non-binary-aware method. Instead of the traditional radio-like button to identify student gender, this approach allows students to write-in their own preferred gender. In our preliminary survey, out of 63 students, two students responded "gender-questioning" and "unknown".

b) An Intersectionality-Aware Data Analysis

As explained in Section 3, data analysis that incorporates the intersectional perspective provides more comprehensive measurements of pedagogies' effectiveness. For example, upon completion of the program, we will examine the relationship between intersectional dimensions, as well as single-facedly. For instance, we will examine the relationship between students receiving financial aid (US government support based on economic need), and their other intersectional identities, such as race and age. The Return to Learning report [30] reveals that older students tend to depend more on financial aid than younger students, supporting the need for an intersectional examination of SES and age in CS. Even amongst financial aid recipients, the level of need shows great variance. To maximize the social dimensions captured within SES, we further classify degree of need based on amount and type of aid received. For example, we compare students receiving Pell Grants (awarded to very low-income students), to those receiving only Cal-Grants (awarded to those with a broader range of family income). This is an ongoing longitudinal study. We will publish the results upon assessment completion.

6 CONCLUSIONS

To conclude, we have demonstrated the critical need to incorporate a multidimensional approach to researching pedagogical diversity initiatives. Through the four elements of social identity: gender, race, socioeconomic class, and age, we have identified the profile of the *fallacious archetype* of a successful Computer Science student. Our aim is, within the field of Computer Science Education, to increase awareness of the needs and benefits associated with applying an intersectional approach. This will improve our understanding of the best ways to address and improve minority representation in the field.

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