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Pathways into Statistics and Data Science for Academically Talented Undergraduate Students with Low Incomes

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Draft Abstract:
Statistics and data science (SDS) is a rapidly growing field, yet this growth is disparate, with individuals holding marginalized identities underrepresented. The developing nature of SDS poses an opportunity to broaden representation and bolster equity via student recruitment and to do so relatively early in the life of the field. In this paper, we investigate how and why a group of academically talented college students with low incomes came to major or minor in SDS. Qualitative coding of student interviews revealed they mostly came to SDS indirectly, were drawn to SDS at least in part by its applied nature, and are unanimously enthusiastic about SDS. These insights into students' experiences with SDS can inform future recruitment efforts aimed at creating a more equitable field.

Introduction

This paper considers pathways that academically talented students with low incomes take into statistics and data science (SDS), which can inform recruitment efforts to build a more diverse, inclusive, equitable, and just field. Popular discussions about socio-political trends increasingly emphasize "data-driven" ideas, boosting the importance of statistical and data literacy for informed participation in our broader communities. However, there is a persistent "digital divide" in which individuals from under-resourced communities have less exposure and access to technological tools and learning [1]. This gap corresponds with new inequalities as technologies are largely developed by and accessible to people with privilege [2], [3]. This makes equitable access to relevant knowledge and skills an important social justice concern.

Research suggests that in SDS, people who are lower-income, Black, Latine, women, and/or disabled are underrepresented in high school coursework and/or the profession [4], [5], [6], [7], which reflects broader trends in STEM more broadly [8], [9], [10]. In addition to helping to equip members of our societies to understand and assess the vast information they come into contact with in their day-to-day lives, expanding participation in SDS will be important as professionals in this field have an increasing presence in the labor market and the broad array of sectors that employ them [11]. The U.S. Bureau of Labor Statistics estimates that the number of data science jobs will grow by 35% between 2022 and 2032, growth it characterizes as "much faster than average" [12]. Appropriate representation in the field could improve the capacity of underrepresented groups to help shape many aspects of life and culture in the United States. In addition to providing a variety of benefits, like enhanced problem-solving and learning [13], [14], [15], this diversity is crucial so that societal structures reflect the needs of all groups that reside in the broader community.

Since SDS is a newer field, there is an opportunity to build equity into it from an earlier stage of development. Ashcraft's "glass slipper" concept underscores the importance of diversifying the field, by articulating how the identities of people in a field shape that field moving forward [16]. For students, having role models who share their identities can help them imagine a future for themselves in a field [17], suggesting that representation may be self-perpetuating. Intentionally building a more equitable field from an early stage of development is crucial for avoiding SDS further homogenizing as it grows in prestige. This may be particularly important since higher-status professions can be exclusive to privileged identities [18], [19].

The related field of computing has an instructive history. It began as a feminized, albeit low-status field before leaders raised the status of relevant occupations and intentionally recruited more men, ultimately making it a persistently male-dominated field [20], [21]. Although it may be easier to do when mirroring existing social hierarchies and pairing a higher-status field with people of privilege, the history of computing suggests it is possible to shift the makeup of a field. Intentional related efforts may be particularly urgent in SDS, since at least one representation gap may be expanding over time: women data scientists decreased sharply from 2018 to 2021, from 31% to 18% of the field [22].

Recruiting and supporting more people from underrepresented groups into SDS requires appealing to members of these groups who are currently in SDS. As such, it is important to understand what drew people from these groups into the field. Research provides some sense of how to achieve this. For example, studies have shown that students who are women and/or from underrepresented ethnoracialized groups have positive experiences and increases in confidence and interest in data-related fields and in research as a result of taking statistics courses that are based on projects that students feel 'passionately' about [23], [24]. Further, members of underrepresented groups have bigger increases in their interest in research than their non-underrepresented counterparts after taking such courses, which suggests that emphasizing the applied sides of SDS may help with expanding participation in the field [23].

In the current study, we expand upon this previous work on how students become interested in pursuing careers in SDS by investigating what drew SDS majors and minors to choose this course of study over other possibilities. We present descriptive and qualitative results from interviews with a group of academically talented students majoring or minoring in SDS and who have low incomes. Based on these results and relevant literature, we offer suggestions for improving recruitment of students with underrepresented identities into SDS.

Methods and Data

This paper relies on data from eight interviews with third- or fourth-year students from several universities in the western United States, who are in their first year of a scholarship program for students with low incomes. All students had declared a major and/or minor in statistics and/or data science at the time of these interviews.

The interview participants come from a group of 28 scholarship recipients from the 2023-24 academic year. We recruited interview participants from the 21 students who had completed a survey, which is another component of the broader research project that includes the present paper. Demographic and socioeconomic background data were captured through the survey. Interview participants reported their race/ ethnicity as Asian (63%), Latine, and/or Middle Eastern/ North African (percentages for the last two groups are at or below 25% and are withheld to prevent deductive disclosure). The majority reported being women (63%) and none reported being nonbinary. One-quarter of participants reported being disabled. In addition to low-income status (measured by Federal Pell Grant eligibility), each of these students also face at least one additional form of marginalization from the perspective of gender, race, ethnicity, or disability status.

The group participating in interviews looks somewhat different from the group of scholarship recipients overall, which had a smaller share of Asian people (50%), women (46%), and people with disabilities (14%), and a larger share of Latine people (32%), and Native American/ Alaska Native people (25%). However, with groups this small, incremental differences can make a substantial impact on percentages. Further, this qualitative research aims to reveal themes rather than provide statistically significant results that are representative of all groups. Nonetheless, one important oversight is that we inadvertently did not recruit any of the Native American/ Alaska Native scholarship recipients to participate in an interview, and we will seek authentic ways to address that for future rounds of data collection.

We used the qualitative data analysis software, Dedoose, to systematically code interview transcripts. We developed the codes in an iterative fashion, both deductively and inductively, to leverage the benefits of existing theory while allowing creative responses to emergent themes that may not fit the literature [25]. To help reduce the possibility of confirmation bias [26] and to maintain consistency, a co-author who did not draft the interview protocol or conduct the interviews coded all of the transcripts, and the first author reviewed the codes for discussion with the co-author. We also used memo-writing to identify emergent themes, track decisions about the coding scheme, and otherwise document our process [27].

Positionality Statement

As a collective, we aim to conduct research that helps expand equity in SDS and STEM more broadly. We recognize that some aspects of equity in STEM have improved over time, yet substantial inequities remain. We argue that, since all communities share our world and face the repercussions of what we build here, all communities should be able to help determine what we create and how we do so, and people in STEM play a large role in creating society's material infrastructure. Further, all people should be able to fully participate in any sphere of public life that they choose. We see addressing ongoing historical inequities as significantly complicated and challenging and aim to attend to as many of its nuances as possible in our work to construct more equitable social systems. As a group, we represent both marginalized and privileged histories and identities (gender, race, ethnicity, and socioeconomic status). Through our combined social statuses, we can relate to some of the challenges faced by students from marginalized groups while needing to continually attend to the biases we hold as we use our power to conduct and share our research with others.

Results

There are three main findings we discuss in this section. First, students generally arrived at SDS majors and minors indirectly. Many had changed their major multiple times and/or homed in on one or more other fields before discovering their interest in SDS. Several discussed past experience studying mathematical or technical fields yet not fully resonating with these areas of study, and some also chose statistics or an earlier field because of a desire to express their creativity. Second, the applied nature of SDS was unanimously appealing to the participating students. Students found the connections to real life appealing. Third, students unanimously shared enthusiasm for SDS, suggesting that their work in this field brings them enjoyment.

Participating students often discovered SDS seemingly by chance. Their general awareness of SDS began as limited, and their initial exposure to the field, when they shared this information,

was often taking a required course or an elective, or being encouraged by a friend or family member to try out a course. One student shared, “I had remembered taking a statistics class, and it seemed really interesting at the time, which was years ago, so I thought I’d try it again and see, and I ended up falling in love with it.” Another student described her pathway: “My best friend is studying statistics as well and she would talk very fondly of statistics, like so much that she was inspiring me to do it.” Yet another student shared that he went to his sister for advice, after he had tried another of her suggestions - computer science - which did not work out: “[My sister] started getting into the field of data analytics. And she's like, ‘Hey, maybe try out a statistics class, see if you like it.’ So from there I took our introductory stat course – fell in love with it and that’s when I decided to change into the statistics major.”

That the students came to SDS indirectly is arguably unsurprising, given that SDS is a younger field and students in primary and secondary schools have relatively little exposure to the field - in 2019, less than one-fifth of twelfth graders who completed a national survey reported having taken a course in statistics or probability by that point in their schooling [4]. This finding also suggests that marketing and outreach of SDS may do a lot to expand participation in the field. While access to SDS in K-12 schools is limited and inconsistent in the United States, there are some efforts to systematically expose secondary students to data analysis [28], [29]. This could do much to help improve statistical and data literacy. Additionally, the field might benefit from programs that hire existing SDS students from underrepresented groups to serve as ambassadors who conduct outreach in high schools (e.g., lead activities, give presentations, engage with students, etc.). Research suggests an approach like this can boost STEM identity if done in a way in which prospective recruits can relate to their ambassadors, for example by recruits and ambassadors connecting while collaborating on a learning activity together [30]. For recruits, sharing identities and/or values with these ambassadors may be especially powerful because this can help foster their senses of belonging [31], which is an important factor in retaining underrepresented groups in STEM [32]. Employing student ambassadors could be a more systematic approach to raising awareness about the merits of SDS than the kinds of ad hoc, one-on-one encouragement that some of the interview participants received from friends or family.

Some students also had interests in being creative, appreciating the opportunity to express this in SDS or discussing artistic endeavors. As one person shared, “I just like turning numbers into pretty visualizations. But at the same time there’s also a meaning behind the numbers as well. That’s just something I really like about it.” One individual, quoted below (“I finally found a subject that was interesting and challenging enough …”), had also spent time in a creative field and appreciated this aspect of that work, but did not feel intellectually engaged.

All students shared an appreciation for the applied aspects of SDS - that there was a clear connection between the learning material and real-world issues and/or that they would be able to contribute to fields of substantive interest to them through working in SDS. Indeed, multiple people described their chosen field as ‘powerful.’ One student did so as follows,

> “I think strategy in general is really interesting, cause you have to be able to think [a] couple of steps ahead, you have to basically think of your future. That’s like a little power, like a little magic quirk that stats has in itself. I think that may have been the reason why I was brought to it [...] the predictive possibilities of statistics.”

Students discussed their pathway to SDS partly through a lens of their relationship with mathematics or a technical field. One example is the individual above who tried computer science before deciding on SDS, which he preferred partly because of the practical significance of the quantitative work he did in SDS. He described moving away from CS as such:

> "I took a few coding classes between middle school to high school. I felt like, okay, this seems pretty interesting so far. And talked to my sister about it and we were like, okay, seems like a good field. You know, computer science is growing and there's potential for growth there, so let's just give that a shot. And I went into computer science, started with the introductory college classes, didn't really like it all that much. It's a bit too technical for me."

This is one of several examples of students who found math or technical fields just 'a bit too technical' or struggled to connect with a field that seemed less connected to real life. One student shared his story as follows:

> "I always liked math but there were always students taking way higher-level math than me. So, I guess maybe it was a lack of self-confidence as I didn't think I was good at math, because I knew of people who were doing much better than me at my age. I never even tried to push myself in that direction. And then college was a shock when I started doing this degree […] We take Calculus 1, 2, 3, 4, linear algebra. And at the time I don't think I enjoyed any of them. But there was a class at the end called proofs and I really liked that one because that was more of a math but in a way like, let's think about it because of the writing math. And I enjoyed that more I think."

While most students who appreciated the meaningfulness of SDS framed this interest as more about how the numbers connect to life, this student found that just spending more time engaged with what the components of the math represent made it more enjoyable. In addition to enjoying numbers that are attached to more meaning, this quote represents another thread in the data in which some students discussed feeling less confidence with math – for example, feeling that the math they had pursued was 'not [their] forte' or that that they were not doing as well as their peers in the subject. However, these students found a home in SDS nonetheless and have been able to successfully complete courses in mathematics, a distinct field that serves as a tool within SDS.

Multiple students also appreciated what they saw as the challenging nature of SDS. One person felt that secondary-level math was too easy for her, after having studied more advanced math in her country of origin but found college-level statistics sufficiently challenging for her. Another individual wanted a course of study that was both meaningful and demanding. She discussed this as follows:

> "I finally found a subject that was interesting and challenging enough for me at the same time. That's why I ended up switching over to stats […] I liked the figuring out problems aspect of math. But I wanted more of a story behind it than just doing calculations. I guess doing calculations was fine, cause I'm not a huge writer, I would say. So, any subjects that made us write tons of papers, I kind of shied away from. I think I've figured out that I like to analyze things more, but like I said math – just doing calculations with no meaning behind it just didn't grab my attention. So, when I found stats that had a

> mixture of – there's a reason why and what we're trying to figure out – I guess it was really what I wanted to do."

This student described a theme that was present in others' pathways to SDS, which married students' interests in problem-solving, working with numbers, and meaningful social issues. This may also have contributed to participants' enthusiasm for and enjoyment in SDS being unanimous, beyond mere interest. In addition to related comments above ("That's like a little power, a little quirk that stats has…," "I finally found a subject that was interesting and challenging enough…," etc.), one student shared that it "is nice getting my education in something that I'm passionate about and find fascinating." Some students even discussed the 'fun' they were having. For example, one individual shared the following anecdote: "One time I was helping [a friend] do like some easy statistics problems. And I was like, this is actually kind of easy and fun. I was like, let me just change majors." Another person appreciated "creating the projects that are pretty fun to do." She continued, "And the statistics - I just felt like data is so powerful when I was taking the courses. So, I felt like really impressed."

Students discussed a range of ways they wanted to use their SDS degrees. For example, multiple students were interested in biostatistics, one of whom came to this interest following a significant health issue they had faced in recent years. Some students also expressed being potentially interested in teaching because of the opportunity to appeal to students. One shared that he would like to "propagate the importance of math, statistics, and understanding all that, in younger generations" and another remarked that "if you do a good job [teaching], you can make class really enjoyable." These students seem to have an inclination toward the kind of student outreach discussed above.

These findings align with earlier research showing that allowing students to apply their coursework to something they care about can pique their interest in additional data-related learning and research [23], [24], demonstrating that this feature of SDS is a draw for people who ultimately pursue a degree in the field. This also aligns with research demonstrating that appealing to students' funds of knowledge, or their accumulated knowledge and interests that they have developed through culturally influenced experience, can help them engage with STEM learning [33], [34].

Discussion & Conclusion

This research adds to the literature about recruiting academically talented students with low incomes into SDS by documenting what drew such students into their major or minor. This is an important endeavor to broaden who can participate in SDS and help shape how the field influences our world, and because improving diversity is a necessary ingredient for expanding equity. Given that students learned about SDS indirectly, through a course or ad hoc encouragement from friends or family, it appears that better outreach could help get the word out about SDS earlier in students' lives and make exposure to the field more systematic, inclusive, and informed. Inspiration for recruitment strategies can also be drawn from existing outreach programs for increasing representation in STEM fields. Successful strategies range from day-long programming in elementary schools [35] to more intensive summer programs for middle-schoolers [36]. To recruit existing undergraduates into a certain major or program, one group of researchers found success in sending eligible students physical, personalized letters, asking them to RSVP for an informal briefing on a career-readiness geosciences program [37]. In addition,

previously discussed ambassador programs can help reach students early in their undergraduate careers. For example, student ambassadors who are current majors in SDS can help by representing the department, participating in recruitment events, and serving as mentors for first-year students [38].

To understand the extent to which pathways to statistics differ based on social statuses (e.g., income, race, ethnicity, gender, disability), it might be useful for future research to document whether and how students across the United States and beyond have become aware of SDS. Based on what resonated for students in the present study, it might help recruitment efforts to emphasize the broadly applicable, powerful nature of SDS, the opportunities to be creative, and current students' enthusiasm for and enjoyment in the field. Highlighting how students can engage with community-oriented values in SDS may also improve recruitment, as past research suggests that seeing the altruistic possibilities of their work in a STEM field may motivate students' future academic and career pursuits [39], [40]. It may also be useful for additional research to directly ask existing SDS students from underrepresented groups how they think the field of SDS can expose more diverse cohorts of students to the excitement of SDS and recruit them into the field.

Students all discussed their relationship to math or a technological field during their story about finding SDS. Some people struggled with confidence in math or appreciated the challenge of working with numbers. At the same time, several students wanted to avoid math or technical fields in which they struggled to find the connection to social life. This suggests an opportunity to connect SDS to more ubiquitous fields like math and clarify how the fields are similar and different. While math and statistics, for example, both involve numbers and calculations, statistics uses math as a tool and requires variables and a real-world application [41]. Sharing this information might facilitate students understanding the field of SDS broadly and may contribute to better recruitment and also retention in STEM. Regarding retention, for example, advisors may encourage students to consider SDS if they enjoy math or computing but struggle to connect with content devoid of context.

This qualitative work aims to establish themes that can be examined for their broader generalizability. Future research should quantitatively assess how widespread the results are and whether there are substantial differences in findings based on various marginalized statuses (race, gender, disability status, etc.). Further, additional research should consider whether and how students' enthusiasm for SDS and the field's real-world applications are sustained into their careers and/or graduate school and what helps these academically talented students from low-income backgrounds stay in SDS beyond their undergraduate programs.

This paper offers insight for expanding and maintaining diversity in SDS, which in turn is important for ensuring that voices from all communities are heard and can contribute to creating the world that we live in. However, an SDS workforce that is more representative of broader society alone is not sufficient to make that world equitable [42]. Socio-politically informed, motivated, and engaged people are necessary to take on work to build inclusion and equity. And given that our world is increasingly shaped and understood through data, statistical and data literacy are arguably increasingly important for activism and other change work [43]. This implies additional research opportunities to consider how recruitment of more members of currently underrepresented groups into SDS may be boosted by and contribute to additional equity change efforts. For example, research suggests that the experience of ethnoracial

marginalization may lend itself to a resistant capital, or knowledge and skills gained through challenging injustice [44]. Integrating social justice topics into SDS may therefore serve the dual purpose of recruiting those individuals from underrepresented groups who have an interest in or connection to social change, while also helping them access tools to work toward that change. While we argue that people from marginalized communities should not be expected to 'fix' systems that oppress them and that it is crucial for people of privilege to engage in social justice work, all people should have the option to participate in these endeavors. Further, diverse voices are, again, necessary to represent broad perspectives and avoid continually perpetuating the same harms. As such, this line of inquiry may be fruitful for equipping a more diverse SDS workforce to make the change necessary for, and by, all communities.

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