"Fast, easy, simple"? SES-diverse transfer students' sociotechnical experiences registering for classes

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Abstract

Recruiting, retaining, and educating students in computing is a frequent research topic in CHI. However, students' sociotechnical experiences of *registering* for classes are understudied—especially those of socioeconomic-diverse students. These experiences matter: research shows that registration problems bring long-term consequences to student successes. We investigate students' socioeconomic status (SES) impact on registration experiences through three studies: a case study with education professionals using an emerging analytic method, SocioeconomicMag (SESMag); interviews with faculty/staff/students from 8 universities; and observations of 14 SES-diverse students registering for classes. Results showed: (1) 5 SES-inclusivity bugs which arose 30 times, 72% more often by lower-SES students than by higher-SES students. (2) 6/7 lower-SES students (but only 2/7 higher-SES students) expected downstream problems from the registration issues. (3) The risk-to-negative-outcomes rate was 3 times higher for lower-SES students. (4) The issues generalized across 8 universities and potentially to >700 other universities who use the same registration portal.

CCS Concepts

• **Human-centered computing** → Empirical studies in HCI. Applied computing; Education..

Keywords

Socioeconomic status, inclusivity, class registration, SocioeconomicMag

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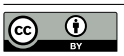

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1 Introduction

In the early days of HCI, the field focused primarily on people interacting with graphical user interfaces (e.g., [87]). Today, however, its scope has expanded to encompass "the *full sociotechnical context* in which specific HCI activities are situated… to understand and

relate observations to their wider… context" (italics added) [48]. One way this sociotechnical scope has proved to be quite powerful has been in uncovering marginalizing designs, social justice, and equity issues not previously understood, such as in agricultural technologies, smart cities, wearables, digital gig work, education, and more (e.g., [22, 26–28, 31, 53, 72, 75, 80, 88, 104]); we discuss this type of work in education later in Section 2.2. In this paper, we follow in these footsteps by bringing a socioeconomic equity lens to the sociotechnical experiences of incoming transfer students.

Imagine "Sam," a transfer student from a 2-year college, now incoming as a Computer Science (CS) major at University X. As a lower-socioeconomic transfer student, Sam has had their share of challenges pursuing their studies. They've been supporting themself and their young child by working full-time at a restaurant, while also attending college full-time. Fortunately, they recently earned a scholarship that will cover University X tuition, as long as they successfully continue full-time in their CS major. Now it's time for Sam to register for classes at University X.

Transfer students like Sam are an important and academically at-risk population. 30% of U.S. students entering a 4-year college/university come from 2-year colleges [108], but less than half of those students complete their bachelor's degree [79, 108]. Like Sam, many students entering universities from 2-year colleges are already in lower-socioeconomic circumstances [79, 108], and transferring can add additional financial risk [79]. Our investigation considers the experiences of 14 transfer students, 12 of whom are transferring from 2-year colleges.

Thus, as a lower-socioeconomic transfer student, Sam is likely to face several upcoming challenges. Still, for their imminent attempt at registering for classes, they at least have the advantage of being a CS major. CS students' extensive experience with technology and problem solving seem likely to be a "best case" for succeeding at tech-heavy experiences like class registration. Given this, investigating the experience of CS transfer students is a conservative approach, because if CS transfer students run into issues registering, these issues are likely to arise for other transfer students at least as often.

In this paper, we present a 3-study investigation into the real-world experiences of incoming CS transfer students like Sam at University X. University X is an HSI (Hispanic-Serving Institute) university located in a large city on the U.S. east coast. 52% of its undergraduate CS/IT students identify with marginalized races/ethnicities that are underrepresented in the computing profession (30% Hispanic, 22% Black). These marginalized populations often have lower-socioeconomic statuses (lower-SES), and in total, 78% of University X's students receive financial aid. The registration process at University X is reasonably representative: it combines University X's own policies/steps with their use of a configurable registration portal used by more than 700 universities in 50 countries. University X's SES attributes, coupled with the representativeness of their class registration workflow, make it an ideal context for this investigation.

In Study 1, Team R, a team of University X faculty/staff/advisors, analyzed University X's registration workflow using an emerging inclusive design method known as SocioeconomicMag (SESMag) [17, 20] to identify inclusivity bugs [39]—user-visible features or workflows that do not equitably support socioeconomic-diverse transfer students. Study 1 provided the socioeconomic lens we use throughout the investigation. In Study 2, we then interviewed 12 faculty/staff/advisors/students across 8 universities whose workflows revolve around the same registration portal, to investigate both the validity and the generality of the issues Team R had found. In Study 3, we then observed 14 incoming University X transfer students as they attempted to actually register for the classes they needed.

Figure 1 (left) shows the workflow University X instructs incoming transfer students to follow. University X's instructions say that this workflow should be "Fast. Easy. Simple" as the bottom of the diagram shows. Perhaps it is "Fast. Easy. Simple" for some students—but if not, whose experiences will be *un*-fast/easy/simple? In this paper, we investigate this central question from a socioeconomic equity perspective:
Are registration processes equitable for transfer students across diverse socioeconomic statuses?

Since this paper focuses on socioeconomic statuses, a definition is needed—but choosing *which* definition is hard. "Socioeconomic status" (SES) is a complex concept referring to an individual's social condition that has been defined in many ways (see [91] for a discussion of many of the definitions). That said, all definitions attempt to capture a person's access to economic and social resources and opportunities. In this paper, when referring to others' work, we accept whatever definition those researchers chose; for our own work, we define a participant's SES as that individual's *perception* of their socioeconomic status as compared to others—which is known as an individual's "subjective SES" [91]—as measured by a validated survey [20] described in Section 3.3.

The term "inclusivity bug" also requires explanation. The term arose several years ago in both the inclusive design (e.g., [64]) and software engineering communities (e.g., [39]). As Guizani et al. explain [39], the term's software engineering roots lie in the testing community's notion of a software failure (sometimes colloquially referred to as a software bug), which Amman and Offutt define as "…external, incorrect behavior with respect to the requirements or … expected behavior" [5]. Inclusive design's requirement/expected behavior is inclusivity across diverse populations, which means inclusivity failures/bugs are features or workflows that do not equitably support diverse users (here, SES-diverse users). Guizani et al. emphasize that, as with Ammann/Offutt's definition, an inclusivity bug is a barrier but not necessarily a "show-stopper." That is, if a particular group of users (e.g., lower-SES) eventually completes their tasks but disproportionately experiences barriers along the way (e.g., confusion, missteps, workarounds), these too are inclusivity bugs against that particular group [39].

Given these definitions, we designed our 3-study investigation to answer the following Research Questions:

- *RQ-SES:* What SES-inclusivity bugs and registration risks do lower- vs. higher-socioeconomic students face when registering for classes, and what do their experiences look like?
- *RQ-Facets:* How do these SES-inclusivity bugs and registration risks relate to SES-diverse students' "facet values" (technology-relevant behavior traits)?

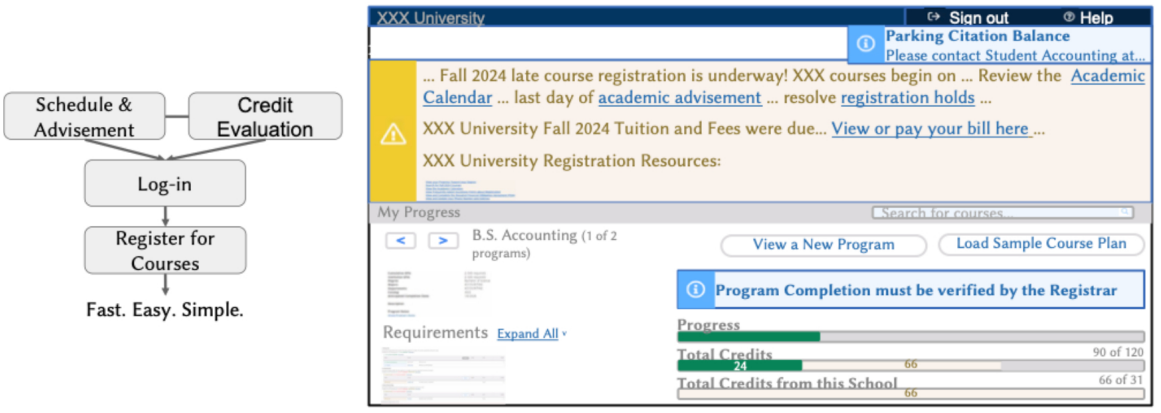

Figure 1: (Left): A visual depiction of University X's registration workflow instructions for incoming transfer students. Students are told to schedule an advising appointment, evaluate the transfer courses they've been given credit for and discuss them with their advisor, then simply log in and register. (Right): Elided registration portal screenshot, redrawn for readability. The page is long, so some areas are shown in unreadably tiny fonts for space, namely: 7 registration resources students can read (blue tiny font), their degree requirements (black tiny font), and several pages of requirements with their progress on each (mostly gray tiny font).

- *RQ-Downstream:* What were the downstream impacts that lower- vs. higher-SES students anticipated from these SES-inclusivity bugs?

By answering these research questions, our paper contributes: (1) the first field investigation from the perspective of socioeconomic equity into SES-diverse CS transfer students' experiences registering for class; (2) the first report of college professionals using the emerging SESMag method [17, 20] to understand SES-equity issues in a university's sociotechnical processes; (3) the resulting SES-inclusivity bugs, registration risks, and downstream problems, triangulated across 14 individual students and 8 universities; and (4) a set of recommendations as to how universities and registration portal vendors could work together to address these SES-inclusivity bugs, registration risks, and downstream problems.

1.1 Positionality statement

We are of multiple races (Asian, Latinx, White), with diverse socioeconomic experiences, and with national/ethnic backgrounds from Asian, South American, and North American nations. Several of us also have the intersectional identity of women of color. Several of us are inclusive design researchers, which motivated our interest in this investigation. We recognize that, as academic researchers and people with access to higher education, we are in positions of privilege. We are committed to using our privileges to contribute to inclusivity wherever technology plays a role, to bring better sociotechnical experiences to everyone.

2 Background and Related Work

2.1 Background: SocioeconomicMag and socioeconomic status

Our work uses the Socioeconomic Inclusiveness Magnifier (SESMag), an emerging analytical method to evaluate if technology is inclusive for individuals across all socioeconomic strata [17, 20]. At SESMag's core are six "facets"—types of individual traits relevant to problem-solving, whose values statistically differ across different SES strata, which we briefly summarize here:

Access to Reliable Technology (Access): Individuals' access to fully functional devices and reliable internet varies by SES. One recent U.S. survey [63] reported that, whereas 82% of higher-SES households (>$150K household income) have a computer device, smartphone, and broadband internet connection at home, only 29% of very low-SES households do (<$25K household income). Internet affordability and availability are especially common issues for lower-SES individuals [11, 81, 83, 101, 105].

Communication: Literacy/Education/Culture (Communication): An individual's ease of communicating with technology is influenced by their literacy, education, and cultural background, and SES can impact any of these. For example, SES impacts literacy levels, even in one's native language, affecting how well users can understand and navigate technology [25, 30]. Communication also includes comfort with complex sentences, specialized vocabulary, and cultural references, all of which are sometimes present in technology's communications [17].

Technology Self-Efficacy (Self-Efficacy) is an individual's belief in their ability to succeed with technology, even when facing challenges or unfamiliar systems. This belief affects problem-solving approaches, persistence, and whether users blame themselves or external factors for difficulties [9]. Studies have found individuals from lower-SES backgrounds to have disproportionately low technology self-efficacy, due to SES disparities in access, education, and experiences [32, 43, 49].

Attitudes Toward Technology Risks (TechRisk): Individual differences aside, lower-SES users tend to engage more conservatively with technology than higher-SES users [21, 44, 45]. Among the reasons are that needing to use shared technology can risk financial independence, and using unreliable technology (recall Access facet) adds additional risks of technology failures or mistakes [44]. Also,

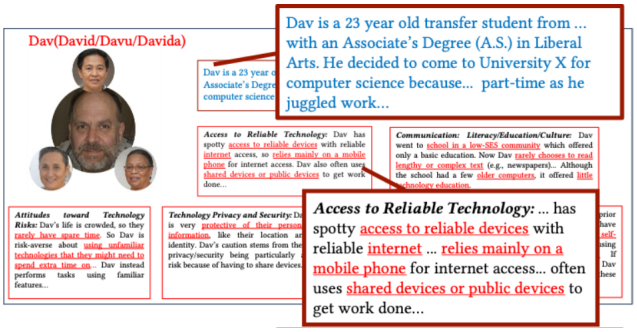

Figure 2: The Dav persona description and the facet values used for Study 1, with two portions magnified here for readability. Photo(s) and blue text (e.g., "Dav is a 23…") are customizable. (See Supp. Docs for larger picture of the Dav persona.)

the risk of losing precious time on irrelevant or obtuse features can particularly matter to lower-SES users if they juggle multiple jobs to make ends meet, or their use of public transportation costs hours [6].

Technology Privacy and Security (Privacy/Security): Concerns about identity theft, online financial fraud, and password hacking are common across all SES strata—but risks of events such as identity theft, online financial fraud, profile harvesting, spying, shoulder surfing, and credit card theft materialize disproportionately often for lower-SES individuals [17, 84]. Lower-SES individuals can also feel particularly susceptible if they must share devices (Access facet) with people they do not fully trust (e.g., [83]).

Perceived Control and Attitude Toward Authority (Control/Authority): The degree of control an individual feels over their life, as well as their attitude towards authority figures, statistically varies by SES [17]. These feelings can affect ways lower-SES individuals interact with technology if they see it as a surrogate authority figure [51, 75, 93]. This can lead to a sense of having no recourse to tech failures and negative outcomes [17].

These six facets are brought to life by three SESMag personas: Dav, whose facet values are statistically most common among lower-SES users; Fee, whose facet values are statistically most common for higher-SES users; and Ash with a third set of facet values [17]. Practitioners can customize certain portions of these personas to suit an application's target audience, but the facet values stay fixed. Our investigation uses Dav (Figure 2).

To find SES-inclusivity bugs, SESMag embeds the facets and personas into a systematic process, namely, a specialized Cognitive Walkthrough [103]. We expand on how we used this process in Section 3, where we discuss the methodology of Study 1. Evaluators walk through every step of the use-case they choose, and answer questions along the way about each subgoal/action a user "should take" to succeed at that use-case, writing their answers on forms for this purpose (an example form is in Supplemental Documents):

- Before taking actions/subgoals: Will <persona> have this subgoal/take this action? Why/what facets?
- After taking the "should take" action: If <persona> does the right thing, will they know that they did the right thing and are making progress towards their goal? Why/what facets?

The evaluators' answers identify "SES-inclusivity bugs" as follows. If the evaluators answer "maybe" or "no" to any of the above questions, it is a usability bug—and if the evaluators attribute this usability bug to a particular SES facet value, it is an *SES-inclusivity bug*, because that bug would disproportionately affect individuals with that SES facet value [17].

2.2 Related Work

2.2.1 Sociotechnical HCI in the domain of computing education. Sociotechnical research has joint origins from organizational research (e.g., [19, 95]), and from another group of authors who saw relationships between societal factors and technology design (e.g., [77, 107]). Since that time, numerous definitions and principles have been proposed for sociotechnical work in HCI (e.g., [1, 12, 67]). In this paper, we follow Donald Norman's definition, which defines a sociotechnical system as a single, unified system where "social and technical elements interact…as interconnected parts of a whole system" [67]. Norman points out that creating such systems requires applying an understanding of social sciences to inform the design of the system's *social and technical* elements (we abbreviate this, social→social&tech. The arrow is pronounced "affects", so social→social&tech is pronounced "social aspects affect social & tech aspects of the unified system".) According to Norman, a prime example is social media [67], in which the social behaviors of users and communities inform the design of the technical elements of social media systems, and users' behaviors with social media systems in turn affect the social behaviors of users [10] (social→tech→social).

Norman lists six principles of sociotechnical approaches. Our work subscribes to all six, with three of them especially pertinent to this paper: Principle 2 states that social and technical elements must be *jointly optimized* to ensure the (joint) system's success; Principle 4 states that the (joint) system must consider the values, safety, and satisfaction of *all stakeholders* to encourage users' well-being and productivity; and Principle 5 emphasizes that sociotechnical systems are *irreducible, that is, these systems need to be considered as whole entities, instead of mere collection of parts* [67].

This intertwining of social issues with technology in the domain of computing education is a frequent theme in HCI. One example is the CHI work on social justice themes for college-level computing education. For example, in the context of HCI education, Oleson et al.'s CHI'20 paper investigated the difficulties HCI college students have in both identifying and avoiding the insertion of their own opinions and biases into the systems they design [69]. Oleson points out that these social influences on technology in turn impact who can engage with the technologies needed to participate in today's computing-infused world (social→tech→social). Wong-Villacres et al.'s CHI'20 paper also investigated HCI education, but from the perspective of how to decolonize it, thereby making HCI knowledge, and the tech systems it affects, more inclusive for diverse countries and cultures around the world [106] (social→tech). To do so, they recommend accepting different cultures' contradicting ontologies and epistemologies as co-existing

ways of knowing that may not align with each other. Garcia et al.'s CHI'24 paper focused on faculty and investigated how to enable them to integrate HCI's inclusive design concepts into all (or most) computer science courses, with the goal of increasing inclusivity of the students' technology products (social→tech). They found that students' new inclusive design practices succeeded not only in improving the inclusivity of the student-built technology, but also in increasing students' social inclusivity toward one another [38] (tech→social). Works with similar goals to Garcia et al.'s are Zegura et al.'s CHI'23 investigation into teaching computing ethics throughout computing education [111], Kuang et al.'s CHI'24 investigation into how to integrate accessibility into core computer science topics [55], and Shapiro et al.'s CHI'20 investigation into teaching data ethics in computer science courses [86]. Overney et al.'s Proc. ACM HCI'25 research goes outside the classroom per se with BoundarEase, a sociotechnical system they created to foster more constructive community engagement around school boundary policies [72] (social→tech). Their results showed that the technology helped to prompt reflection among community members on how their school policies might impact families other than their own, and increased transparency around the competing policy proposals (tech→social).

Also relevant to our work are sociotechnical works outside the HCI community that focus on specific populations of students and how to bring more inclusivity/equity to those populations. These works tie to sociotechnical systems in that excluding *who* can join the ranks of CS majors (social→social) affects the tech that future technologists create (social→tech). For example, Rankin et al.'s research exposes how systems of power and privilege in CS education are often used against Black women across the entire CS educational pipeline–from K–12 through undergraduate and graduate study, and even into CS faculty experiences [80]. They reported that an intersection of racism, sexism, and classism serves as a system of oppression that pervades CS education at every level, and point to the area of health science education as offering alternative approaches that could be brought to bear on these problems in CS education. Numerous other researchers have also investigated CS post-secondary education for minoritized groups (e.g., [37, 57, 70, 80, 82, 94] and many more).

Still, only a few of these sociotechnical investigations have considered students' SES diversity as factors in CS education—our primary focus—and with a few notable exceptions, most of that work investigated middle- and high-school students (e.g., [61, 65, 74, 85]). One of the few that did investigate SES-diverse students in post-secondary CS education showed that SES impacts students' likelihood of enrollment in post-secondary education [71]. As of 2022, a little more than 50% of all US high-schoolers were lower-SES, but their representation in college computing classes drops dramatically, with 11% fewer lower-SES students in CS classes as compared to their peers; for advanced CS classes, lower-SES students are 20% less likely to even enroll [102]. Studies of transfer students in CS college-level courses, who also tend to be lower-SES students [79, 99], likewise point to these students being at risk. Being a transfer student adds an additional layer of challenges unique to them [56, 79]; in some of the literature, the term "transfer shock" is used to capture "a severe drop in <academic> performance upon transferring" [47, 56]. Kwik et al. further suggest that CS transfer students may experience even more challenges than other majors, due to the known inclusivity issues in much of CS education, and attested to by research showing STEM transfer students having severe grade drops that many other students did not [56].

These investigations show that lower-SES students in CS education are particularly at risk. However, none of these studies investigated SES-diverse transfer students' sociotechnical experiences registering for classes.

2.2.2 Social or technical research specifically on class registration issues. The sociotechnical registration system is important because research has shown that registration issues matter to academic success. However, much of this research takes a strictly social→social perspective, i.e., focusing on how social issues/behaviors affect students' social outcomes. For example, registering late correlates to lower academic performance; e.g., lower GPA, course completion [68]. Tompkins et al. also found late-registering students to be about 50% less likely to pass a course when compared to on-time registrants [92]. Similarly, Bohler et al. found that online STEM students registering late earned, on average, one letter grade lower than students who registered earlier [14]. This is consistent with Phelps et al.'s study, which also found a correlation between late enrollment in introductory CS classes and student performance [76]. Closer to our investigation is work by Hug, who found that college students with diverse backgrounds and resources have differing needs in the registration process [50]. This work investigated STEM students' persistence during registration and found it important to provide additional staff support, particularly from staff with expertise in finance, administration, and counseling (social issues→social solutions). These studies, however, did not investigate how the socio*technical* registration process may itself create barriers to SES-diverse students' enrollment.

Other research has instead focused on technical but not social aspects by investigating registration portals' UI usability issues (tech features→issues with the tech). For example, Estevez et al. investigated the efficiency and performance of a web-based course registration portal to overcome the tech's usability issues such as students not understanding when registration was complete, accessing multiple web pages, searching, adding courses, and viewing class schedules [34]. Another study found that students' perceptions of a registration portal's ease of use and utility was impacted by the quality of information, innovation, and services provided by the system [42]. Another study on registration portal usability reported several accessibility barriers in university registration websites, including excessive browser tabs, redundant information, and missing summaries for data [3]. These works explored the technical usability of the registration systems, but did not consider the impact of students' SES in their sociotechnical experience with the registration system.

In fact, none of these investigations bring together the sociotechnical experiences of computing transfer students, or on how SES may influence students' sociotechnical registration experiences. That is the gap this paper aims to fill.

3 Methodology

To investigate our research questions, we conducted three empirical studies, which Table 1 maps to the RQs.

Table 1: Overview of the three studies (Study 1=first column, Study 2=second column, Study 3=third column), and their mapping to the investigation's RQs (bottom row).

Who	**Study 1 (Case Study)**: Team R, a group of educ. professionals led by Univ. X's Registrar.	**Study 2 (Interview Study)**: Faculty/advisors/staff/students at 8 universities.	**Study 3 (Think-aloud in Case Study)**: 14 SES-diverse CS/IT transfer students at University X.
Why	To identify potential SES-inclusivity bugs and registration risks.	To validate & investigate generality of Study 1's SES-inclusivity bugs and registration risks.	(1) To further validate Study 1's results. (2) To investigate students' experiences. (3) To investigate downstream problems.
Activity	Team R used SocioeconomicMag (SESMag), an analytical method, to identify registration issues that may disproportionately affect students at particular SES levels.	Interviewees answered if they had seen/heard of a student experiencing Study 1's SES-inclusivity bug/registration risks.	Students (1) answered validated surveys, then (2) tried to register for their classes, then (3) answered whether they expected any downstream problems.
For	RQ-SES, RQ-Facets	RQ-SES	RQ-SES, RQ-Facets, RQ-Downstream

3.1 Study 1: Case Study of Education Professionals using SESMag

Study 1 was a specific form of field study known as an empirical case study. Yin defines an empirical case study as "an empirical inquiry that investigates a contemporary *phenomenon* within its *real-life context*, especially when the boundaries between phenomenon and context are not clearly evident" [110] (italics added). The *phenomenon* we investigated was college professionals using SocioeconomicMag (SESMag) to find *sociotechnical* inclusivity bugs in the *real-life context* of University X's class registration. Note that because of the emphasis on investigating a real-life context with no artificial controls, empirical case studies are not intended for *population* generalization. Instead, they aim for *theory* generalization; e.g., the applicability of a theoretical framework to a new situation [110]. In our case, the case study investigates SESMag's applicability to college professionals using it on University X's class registration.

The case study came about because the Registrar's Office and CS Department Chair were particularly interested in class registration SES-inclusivity bugs that disproportionately affect students with lower-SES. To identify these bugs in their registration workflow, University X's Registrar's office led a team of registration-involved faculty/staff in an SESMag session as per Section 2.1. The session evaluated the registration workflow using "Dav" as the persona (recall Figure 2), as Dav attempted to register for classes.

3.1.1 Participants & Procedures. Before the session, we held a 30-minute meeting with the CS Department Chair and two representatives from the Registrar's office to: (1) explain SESMag and how an SESMag session works; (2) prompt them to pick one of their *own* registration use-cases (they chose Table 2's); and (3) prompt them to decide which of their extended team (registration-involved faculty/staff) to invite. They did so using purposive sampling (a form of non-random sampling that selects members of a population according to specific characteristics [59])[1], because SESMag evaluations are meant to be done by people who have agency to fix the inclusivity bugs they find [17, 20]. It is for this reason that university administrators guided the sampling process for Study 1. (However, they were not involved in the sampling or recruitment of Study 2 or Study 3.) By this method, they chose the University Registrar for overall expertise on administrative interdependencies in University X's sociotechnical registration process, the Registrar's two technical leads for technical expertise with the registration portal, and University X's lead advisor and the CS Department Chair for expertise with students' socio+technical issues with registration. Two researchers also joined the team as participant-observers [41] to facilitate the sessions and to record the team's work. From this point, we refer to these participants collectively as "Team R." Team R then (4) chose the use-case of an incoming student for the evaluation ("Dav" attempting to register for classes). Finally, (5) they customized the "Dav" persona to be an incoming CS transfer student (shown earlier in Section 2, and in the Supplemental Documents).

During the SESMag session, after collecting IRB consent from each participant, one Team R member "drove" the prototype, specifying the subgoal and actions they hoped Dav would take throughout the registration process. The two researchers served as facilitator and recorder, and all Team R members acted as evaluators. Each team member answered the *subgoal*, *before-action,* and *after-action* evaluation questions specified in Section 2.1, along with facets that contributed to their reasoning. SESMag embraces differences of opinions among evaluators, so everyone's evaluation decisions were added to the SESMag form (template provided in Supplemental Documents) at each step, with no requirement for consensus among the members of the team. We recorded this 2-hour Zoom session (screen and audio data) with participants' consent using an IRB-approved consent document. Table 2 shows the use-case, subgoal, and actions that Team R evaluated during Study 1.

3.1.2 Analysis. After the SESMag session, we collected the subgoal and action forms Team R had completed. As per the SESMag Method (Section 2.1), each time Team R gave a "maybe/no" response

[1]Purposive sampling may or may not be somehow representative of a population, but triangulation with other data sources can help mitigate such threats [59]. Our investigation triangulates Study 1's results with Study 2 and Study 3 data.

Table 2: Overview of the scenario, subgoal and actions from the SESMag session in Study 1.

Use-case (Overall Goal)	Subgoal	Actions
New transfer student wants to register for the classes they're supposed to take	Seek advisement and figure out which classes need to be taken	(1) Go to application portal (2) Click "View Your Progress" (3) Click on "Requirements"

and explicitly specified any of the six facets as part of their reasoning indicates an "SES-inclusivity bug". The evaluators' reasoning ("why" section in the SESMag forms) for each bug that added potential causes we denote as "registration risks." We enumerate each SES-inclusivity bug and registration risk in Sections 4 and 6, respectively. These lists of Team R's inclusivity bugs and risks then served as codesets for Study 2 and Study 3.

3.2 Study 2: Interview Study of Faculty/Staff/Students Involved in Registration

3.2.1 Participants & Procedures. To both confirm validity of the SES-inclusivity bugs and registration risks that Team R identified in Study 1, and to assess whether those bugs and risks were unique to University X, we recruited interviewees to tell us whether they had witnessed these bugs at their own universities, using snowball sampling[2] [59, 73]. Specifically, we gathered as complete a list as possible of North American universities using the same registration portal, via a list the vendor provided, individuals from Team R, and individuals at universities Team R knew to be using this registration portal. Of the 38 contacts we invited, 5 were Team R members at University X. The rest were not guided by University X administrators: the vendor provided 4 contacts (not at University X), a University X faculty member on Team R provided 20 contacts (not at University X), and non-University X researchers on Team R contributed 7 contacts (not at University X). We then contacted all 38 of the contacts on this list. 12 individuals agreed, together representing 8 universities.

The interviews were semi-structured, i.e., starting with questions about the SES-inclusivity bugs or registration risks found in Study 1, and then flexibly following up with additional questions based on interviewees' responses. We chose a semi-structured interview because it focuses interviews around one or more fixed questions, but also allows the investigator to explore pertinent ideas that may come up during the interview [4, 13]. Our fixed questions were of the format "Have you ever seen or heard of a student experiencing <SES-inclusivity bug or registration risk from Study 1>?" which are listed in full in the Supplemental Documents. After conducting several pilot runs, we asked these questions to each interviewee, following up as needed as per the semi-structured interview method [4, 13]. Each interview began by obtaining the interviewee's IRB-approved consent, then proceeded with these questions. We conducted each interview one-on-one via Zoom for 30-60 minutes, recording screen and audio data. To avoid influence from university administrators, all interviews were conducted by a student researcher alone, with no University X administrators/staff present (unless they were being interviewed).

3.2.2 Analysis. We transcribed the interviews' audio recordings and divided each transcript into one segment per question response. We qualitatively coded each segment by the particular bug/risk the interviewee confirmed witnessing at their university. More than one code/segment was allowed. The codeset consisted of the SES-inclusivity bugs and registration risks Team R identified in Study 1, which are enumerated in the upcoming Results sections (also provided in the Supplemental Documents). Two researchers independently coded 20% of the data with an inter-rater reliability (IRR) of 83% (Jaccard). Given this acceptable IRR [89], one researcher finished the rest of the coding.

3.3 Study 3: Think-Aloud Protocol in Case Study of Transfer Students

An underlying principle of case study research is use of multiple sources of evidence and triangulation [110], so to further validate Study 1's SES-inclusivity bugs and registration risks, we triangulated Study 1's results with the experiences of SES-diverse CS transfer students as they attempted to register for their own classes. As with Study 1, Study 3 was an empirical case study [110] in the *real-life context* of University X's class registration, but in Study 3 the *phenomenon* we were investigating was SES-diverse CS transfer students' sociotechnical registration experiences.

3.3.1 Participants. The normal process at University X is that all incoming transfer students must meet with an advisor and then register. As part of this process, we invited all incoming CS/IT transfer students to let us watch them register, offering $40 as an incentive (census "sampling" [52]). 15 students accepted, but one student had already registered, leaving 14 participants. All participants read and signed an IRB-approved consent form. Students who completed the study were compensated with a $40 gift certificate.
Of these 14 transfer students, 12 were transferring directly from 2-year colleges; 1 had previously transferred from a 2-year community college to a 4-year university and now was transferring to University X; and 1 participant was transferring directly from another 4-year university. We did not collect genders or ages.

3.3.2 Procedures. To answer *RQ-SES*, we required students' subjective SES (perception of their socioeconomic status relative to others). We measured this using a validated Subjective-SES Survey [20], in which participants answered 4 questions consisting of their rating of their own wealth, of their parents' education, how comfortably they live, and their food security (the survey [20] is

[2]Snowball sampling's selection bias can render it unsuitable for statistical representativeness calculations, but it is valid for triangulation purposes as with our Study 2 [59]. Simply put, Study 2's interviews are not about representativeness, but rather serve as triangulation with Study 1's "there exist" results (e.g., there exists SES-inclusivity Bug #1 in real context(s)).

included in the Supplemental Documents for convenience). We then computed each participant's subjective SES score as the sum of the weighted products of the participant's responses, as per [20]. For our investigation, we considered participants with SES scores below the median to be lower-SES relative to their peers, and those above to be higher-SES relative to their peers. No student's score fell exactly at the median.

Likewise, answering *RQ-Facets* required students' SESMag facet values (recall Section 2.1), which we measured using participants' responses to a validated SES-Facets Survey [20]. This survey asks 3-4 questions about each SES facet from Section 2.1, and is included in the Supplemental Documents for convenience. Similar to the subjective SES calculations, we computed the participants' facet scores using the sum of the weighted products of the participants' responses to questions about that facet, as per [20]. Following the procedure in [20], we then labeled a facet value as "Dav-like" when the facet score was below the median, or "Fee-like" when above the median [20].

To comply with University X's requirement that students see an advisor prior to registering, and to ensure a common starting point for all participants, each participating student needed advising. If they had not already arranged an advising appointment, we connected them with a CS faculty advisor for a 30-minute advising appointment. To minimize power dynamics or pressure on the participants, the advising session was private and not collected as data, with no observers or recording. Immediately following their advising appointment, we transitioned to the Study 3 session.
We took several additional measures to minimize potential for power dynamics or pressure that might influence students' responses during the Study 3 session: (1) neither the advisor nor any other University X faculty/administrators were present during the session; (2) the researchers who conducted the session were near-peer student researchers; (3) the consent form participants signed prior to the session informed them that nobody except the researchers would see their data, and further that their participation would not affect their grades or standing with the university; (4) because University X is a Hispanic-Serving Institution, we ensured that at least one student researcher in every session was Hispanic and fluent in Spanish.

To capture students' registration experiences, we followed a concurrent think-aloud (CTA) protocol to capture as many insights as possible into what SES-diverse students were thinking and feeling[3]. Research has shown the value of the think-aloud method compared with other methods [23, 29, 62, 90], and particularly that the concurrent think-aloud (CTA) protocol reveals more problems than a retrospective think-aloud [2, 78]. We chose Boren and Ramey's CTA, which uses speech communication theory to target usability issues [15] in ways which Ericsson and Simon's more rigid cognitive science model [33] does not. A comparison between the two protocols for usability testing found that Boren and Ramey's method yielded higher rates of task completion and participants were less lost [54].

As per the CTA protocol [15], we first had students practice thinking aloud: one researcher first demonstrated thinking aloud, then invited the student to practice it ("count the windows in your childhood home"). After practicing, we gave each student a direct link to the registration portal and asked them to sign in. Once they had logged in to the registration portal, we asked them to go ahead and register for their classes: "…go through the <registration portal> and explore, plan, schedule, and add any courses you are planning to take during <the upcoming term>." We did not intervene unless students could not log into the registration portal, as noted later in Section 4.2. Students could participate either co-located with one researcher with a second researcher on Zoom, or with everyone on Zoom; in all cases, we recorded video and audio with Zoom. Each session was time-boxed to 2 hours, and if the participant couldn't complete their registration in the first session, we scheduled a second session to allow them time for offline steps (e.g., reaching out to an advisor for further advice, approvals, etc.). For second sessions, we resumed wherever they had left off.

Finally, to both supplement the *RQ-SES data* and answer *RQ-Downstream*, we followed each student's think-aloud session with a semi-structured interview. Some research suggests that semi-structured interviews have strengths complementary to concurrent think-alouds: they are better than concurrent think-aloud protocols for eliciting comments on usability, but suffer from positive bias [97]. Using both methods allowed us to benefit from the strengths of each. Thus, during the interview, we asked students about their registration experiences, and also for *RQ-Downstream,* Question #7: "Of these problems that you encountered… Do you think this is going to cause problems down the road? (EX: Does this mess up your scholarships, class prerequisites, etc.?)" See Supplemental Documents for the full list of questions.

3.3.3 Analysis. After transcribing the think-aloud data and interviews, we segmented the transcripts at every >=3-second gap between utterances, resulting in 2,996 unique utterances. To qualitatively analyze the segments, we used the same SES-inclusivity bugs and registration risks codeset as in Study 2, but slightly adapted to accommodate students experiencing the systems in a different context (using a computer instead of a mobile device which resulted in different UI components). The codeset adaptions are reflected in Section 4.3 and the final codeset for Study 3 is in the Supplemental Documents. Two researchers reached an 81.81% IRR (Jaccard) agreement on 20% of the data, after which one researcher coded the rest. We used all the results of this coding (except Question #7) to answer *RQ-SES* and *RQ-Facets*.

We then used the results of Question #7 to answer *RQ-Downstream*. Although responses could include problems beyond inclusivity bugs, our analysis focused on responses related to inclusivity bugs. We qualitatively analyzed the responses, with two researchers independently coding the responses into a "yes/maybe/no" (codeset in Supplemental Documents) with an IRR of 100% on 20% of the data. Given this agreement, one researcher coded the rest.

4 Results: The SES-Inclusivity Bugs and their facets

In evaluating students' sociotechnical experiences in University X's registration workflow (recall Figure 1), Team R found 5 SES-inclusivity bugs for SES-diverse students trying to carry out that

[3]While thinking aloud cannot truly access a person's thoughts [66], it offers more insights into their thought processes than silent observation [23].

TEAM R		INTERVIEWEES													STUDENTS		
Study1: SESMag Walkthrough (a)		Study2: Witnessed events (b)													Study3: by SES (c)		
		SES-Inclusivity Bugs															
	Why? (which facet(s))	I-X1	I-X2	I-X3	I-X4	I-X5	I-U1	I-V1	I-W1	I-Y1	I-Z1	I-A1	I-B1	Tot	Lower-SES	Higher-SES	Tot
Bug #1: Problems with advising	Comm., AccessReliable, Ctrl/Authority	✓	n/a	✓	✓	✓	n/a	✓	✓			n/a	✓	7/9	✓✓✓✓	✓✓✓	7
Bug #2: Trouble accessing registration portal	Comm., AccessReliable, Self-Efficacy		n/a	✓		✓	✓		✓	✓		✓		6/11	✓	✓	2
Bug #3: Didn't check prior course credit	AccessReliable, TechRisk, Ctrl/Authority			✓	✓	✓		n/a	✓		n/a	✓	n/a	5/9	✓✓✓✓✓ ✓✓	✓✓✓✓ ✓	12
Bug #4: Didn't check requirements	AccessReliable	✓	n/a	✓	n/a		✓	n/a	✓	✓	✓	✓	✓	8/9			
Bug #5: System missing progress info	AccessReliable	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	10/12	✓✓✓✓✓ ✓✓	✓✓	9
		3	1	5	3	4	2	2	5	3	1	4	3	36	19	11	30

Figure 3: (a) Study 1: SES-inclusivity bug & facets Team R tied them to. Bug #3+4 combined for consistency across studies. Blank: no evidence from this source, n/a: not/applicable (Study 2: interviewee did not answer this question) (b) ✓: (for Study 2): one instance of interviewees giving evidence of an SES-inclusivity bug (c) ✓: (for Study 3): one instance of a student running into this SES-inclusivity bug shown by their SES

workflow. Figure 3a lists these SES-inclusivity bugs. As Figure 3b shows, multiple interviewees from Study 2 confirmed having seen/heard evidence that all of these bugs had also occurred at their own universities. In Study 3, the students themselves actually ran into all of these bugs when they attempted to register for their classes. In fact, as Figure 3c shows, they encountered them 30 times (bottom of rightmost column). Students did not encounter these bugs in any particular order.

Recall from Section 2.1 that an SES-inclusivity bug is defined as a maybe/no response that the evaluators attributed to a mismatch with Dav's facet value(s). Such a mismatch suggests that the bug would disproportionately affect students with Dav-like facet values, which the foundational literature (Section 2) associates with lower-SES individuals. As Figure 3's totals show, the students confirmed the disproportionality: lower-SES students faced 72% more occurrences of these SES-inclusivity bugs than their higher-SES peers did.

4.1 SES-Inclusivity Bug #1: Problems with advising

Before a student tries to register using the registration portal, University X *requires* the student to meet with an advisor. To make sure the students know this, University X sends instructions to the student to seek advising. Yet, during Study 1, Team R realized that students did not always know this, or even if they did, they did not always do it. This realization became Team R's Bug #1:

> Team R (eval. form): "...<students> didn't come to us asking for help, they went to one of their older friends... "

Indeed, as Bug #1 in Figure 3b shows, 7/9 interviewees in Study 2 reported having seen this bug among past students, and in Study 3, the students experienced advising problems themselves 7 times. This problem arose only a little more often for lower-SES students than for higher-SES students (Figure 3c)—but the facets were much more revealing.

Team R associated three Dav-like facet values with Bug #1. First was Control/Authority. Team R pointed out that students with Dav's Attitude Toward Authority might be uncomfortable going to an authority figure such as an advisor. Second, Team R brought up the Access facet—because of Dav's use of shared devices, Dav could miss seeing the university emails instructing him to seek an advisor.

> Team R (eval. form: Ctrl/Authority): "Dav is not particularly comfortable going to authority figures because given his background... turning to his friend sounds like a darn good idea."

> Team R (eval. form: AccessReliable): "Based on this access ..., he goes to the library and uses public devices... he may not read the, the communications that goes out."

But Team R's main reason for seeing Dav as being disproportionately disadvantaged was the Communication facet:

> Team R (eval. form: Comm.): "Our correspondence that goes out from the school at times is pretty lengthy... it goes out often, and so... <Dav> may not read the, the communications ... that may be too overwhelming..."

As Figure 4 shows, Team R's concerns were well-founded. All 6 students who encountered Bug #1 had at least one of the 3 Dav-like facet values Team R had identified as being poorly supported. And indeed, Communication was involved the most. For example, lower-SES students S12 and S14 both reported Dav-like Communication facet values in their survey responses: S14 reported below-median English literacy, S12 reported below-median prior education quality, and both reported very low comfort with US cultural references and prior technology experience in their schooling.

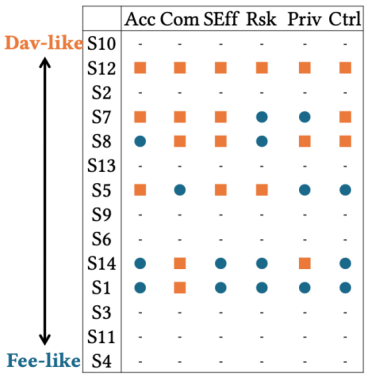

Figure 4: Bug #1: Students experiencing Bug #1, ordered by #Dav-like facet values (squares) to # Fee-like facet values (dot). -: students who didn't experience this bug. Bug #1 impacted mostly students with Dav-like Communication ("Comm.").

Team R noted that the only way students would know to seek advising was through university emails. Figure 5 shows the numerous communication barriers in these emails: long, complex sentences, difficult readability, advanced vocabulary, specific cultural references (e.g. "Dreamers"), and more. Any of these could overwhelm students with Dav-like Communication facet values, like S12 and S14.

Still, not all encounters with Bug #1 were about language and cultural references. S14 tried over and over to schedule an appointment with an advisor, but each advisor referred them to another advisor, until S14 finally managed to get advised from the department chair (Figure 6). S14 summarized their experience this way:

> S14 (lower-SES): "I just wanted to get … someone from the school to kind of put me in the right direction… It's kind of hard to get in touch with people here."

4.2 SES-Inclusivity Bug #2: Trouble accessing registration portal

During Study 1, Team R noticed potential barriers accessing the registration portal, which they identified as SES-Inclusivity Bug #2. They expected students with a Dav-like Communication facet value to be at risk for this bug:

> Team R (eval. form: Comm.): "Dav doesn't even know which email is supposed to take him to the application portal."

As Figure 3b shows, in Study 2, 6/11 interviewees confirmed having seen this bug arise in the past…

> Researcher: "Have you ever heard of a student who didn't go to… the <registration> portal?"
>
> I-X3: "Yes, absolutely. … We dealt with this all summer."
>
> Researcher: "Have you ever seen or heard of a student who is unable to access the registration portal?"
>
> I-U1: "Yes… that's usually a setup on the IT side of things… I don't think all those things always fire off like we designed them to."

…and in Study 3, Bug #2 arose for two students. For example:

> Researcher: "…you can go ahead and get started with the scheduling…"
>
> S3: "Is there a way to register my password, or something, because I don't think I made one for this?"

S3 (Fee-like Comm. facet value) and S11 (Dav-like Comm. facet value) are the two students who experienced Bug #2 (Figure 7). Despite their apparent communication differences, a closer look at

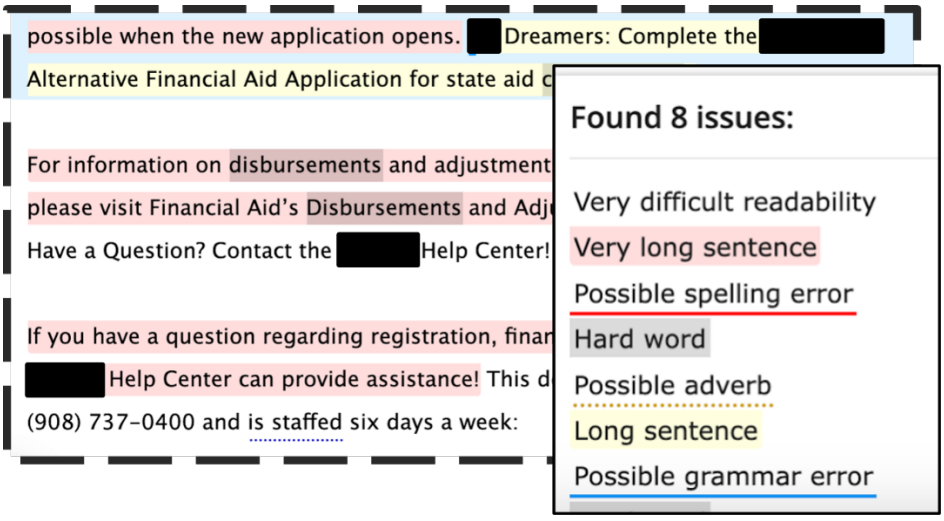

Figure 5: An email sent by University X to an incoming student. A readability checker (readable.com) detected the readability issues shown (magnified for readability), relevant to Dav's Communication facet value.

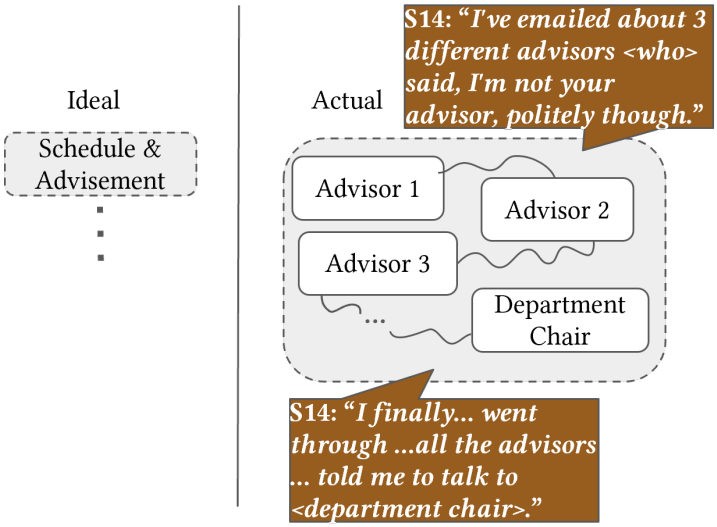

Figure 6: Bug #1: University X's instructions (left) versus S14's attempts to get advising (right). S14 went through multiple advisors before finally arriving at the Department Chair for advising.

their survey responses to the Communication facet revealed two communication-related similarities: both students' facet responses were below the median in both education quality and previous technology experience.

Their low previous technology experience may have been particularly involved with Bug #2. In the log-in situation, a student's technology mental model would need to understand the different systems involved and how they are linked; otherwise, a student may misunderstand *which* login credentials they need. In total, S3 and S11 took over 17 and 7 minutes, respectively, to log into the registration portal while they tried out different options and dug around through past emails. In fact, S3 and S11 were so stuck, researchers finally had to step in and get them logged in, to enable the study to continue. In contrast, the four students scoring above the median in both quality of education and previous technology experience took a maximum of 1 minute and 4 seconds.

For example, S3 tried to register but immediately hit a roadblock—they did not know whether their account had been created, and if so, what their new account information was. S3 experienced several setbacks, including logging into multiple accounts, searching through old emails to find their acceptance letter, etc., *before* they could begin to register (Figure 8). S3's experience is consistent with Team R's quote above about a student not even knowing which of the university's complex emails (recall Figure 5) would have the needed information.

We were surprised that *any* student encountered Bug #2. Recall from Section 3.3 that in Study 3, we provided all student participants with a direct link to log into the registration portal. And yet, two students still struggled to access the registration portal. S3 and S11's experiences reveal that even if students knew where to go, they didn't always know how to get beyond that point.

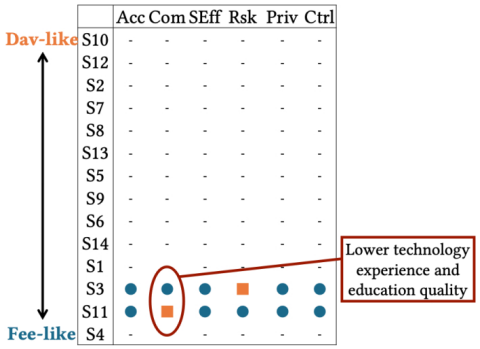

Figure 7: Facet values of the students who experienced Bug #2. Colors: same as Figure 4. Superimposed: the students' prior education quality and tech experience.

4.3 Combined Bug #3+4: Didn't check prior/required course credit

According to University X's instructions, transfer students should check their progress (prior course credit) and upcoming requirements to make sure they've satisfied the necessary prerequisites for their courses. But would a student, eager to complete registration, check their progress (Bug #3, Figure 9) and/or requirements (Bug #4, Figure 10)? Team R didn't think so:

> Team R (eval. form: AccessReliable, Ctrl/Authority): "... the student would go to 'Plan and Schedule'... they want to get registered... if I didn't have access to reliable technology like Dav, I would want to get as much done with whatever I had."

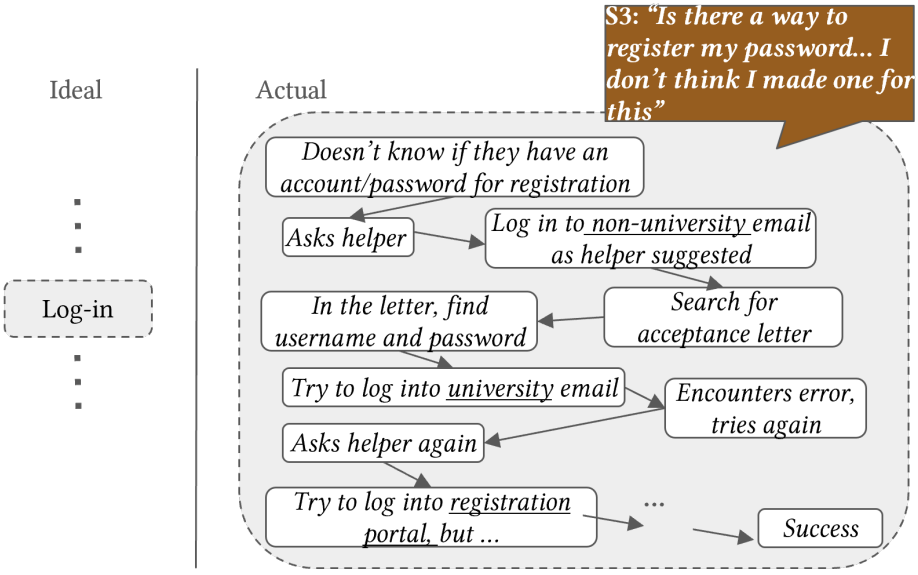

Figure 8: Bug #2: S3's experience attempting to log into the registration portal. Notice how S3 encountered several setbacks before being able to log in.

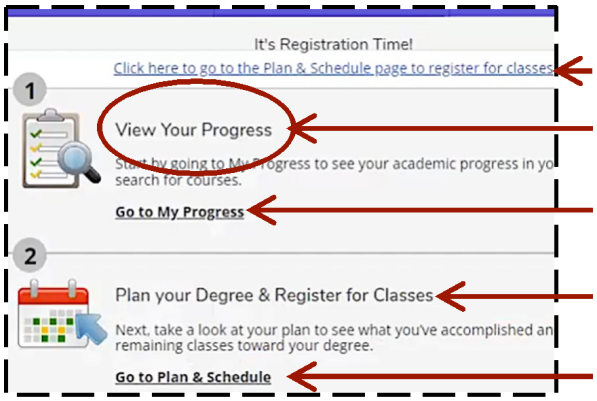

Figure 9: Bug #3: At this point, Dav is supposed to click "View Your Progress" (superimposed circle) to figure out the classes he needs. However, Dav's goal (register for classes) also matches other 4 options (superimposed arrows).

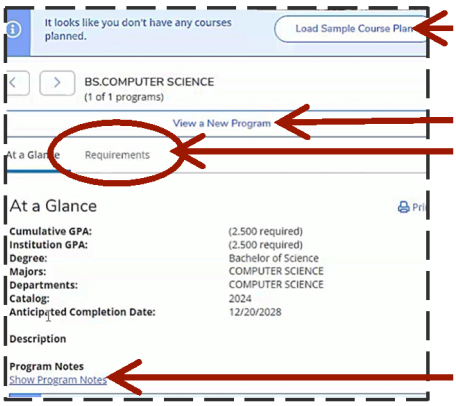

Figure 10: Bug #4: At this point, Dav is supposed to click "Requirements" (superimposed circle). But it appears to be grayed out, and competes with 3 other relevant clickables (superimposed arrows).

Study 2's results strongly agreed. 10/11 interviewees confirmed one or both of these bugs[4] and pointed out serious consequences that sometimes arose from these bugs. For example:

> I-U1: "Yes, I've seen it before where that student applies for graduation, and then ... somewhere along that line someone realizes you're not eligible to graduate yet, because you missed this requirement."

> I-Z1: "...because they did not actually check their requirements correctly, and did not ... sign up for the right amount of credit each semester, and then they had to...take more credits in the next semesters..."

Given such serious consequences, Study 3's results for Bug #3+4 were alarming—12/14 students skipped checking their progress and requirements. Of those 12 students, 7 were lower-SES students, including S9. For S9, this prevented them from registering for a class they needed (Figure 11).

[4]Students in Study 3 chose to register with laptops instead of on mobile devices as Team R had assumed (recall Section 3.3.3). Because the system's UI for laptops groups students' prior credit and requirements together on one screen, we combine these bugs for analysis of Study 3.

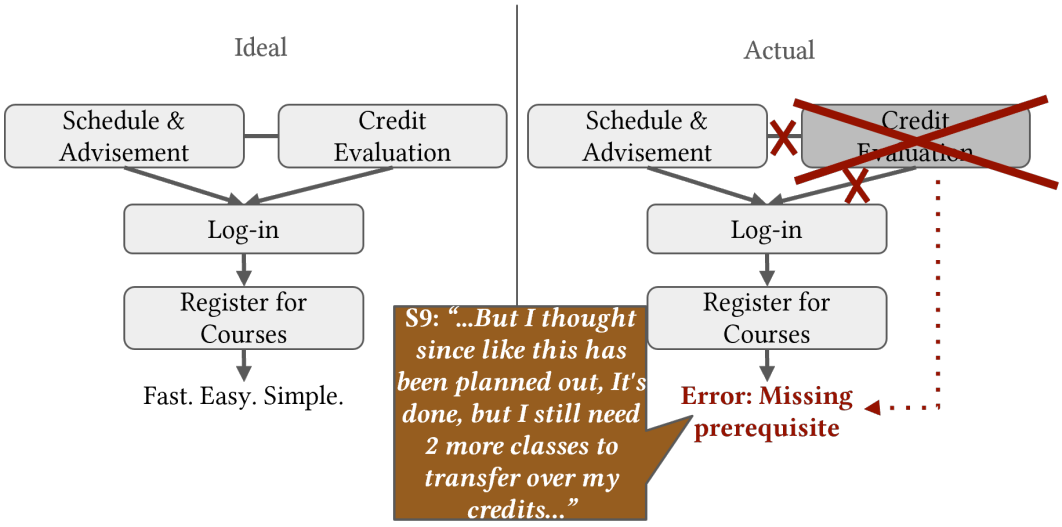

Figure 11: Bug #3+4: S9's experience. (Left): The workflow as per University X's instructions. (Right): What really happened: S9 skipped the credit evaluation step—then could not register for a class due to a missing prerequisite.

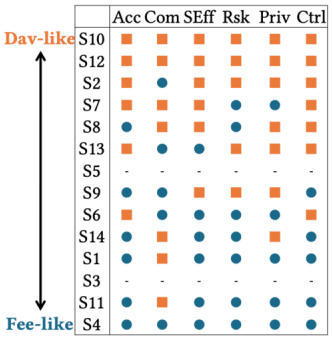

Figure 12: Bug #3+4: Facet values of the students who experienced this bug. Note that the majority of the students encountered this bug. Colors: same as Figure 4.

On the surface, the near universal nature of Bug #3+4 might suggest that it is an "everyone" usability bug rather than an SES-inclusivity bug. However, the "everyone-ness" of this bug stems from two different facets affecting lower- and higher-SES students' behaviors. For lower-SES students, the Dav-like Control/Authority facet value (facets shown in Figure 12) led them to defer to advisors' guidance, sometimes leading to incorrect paths:

> S2 (Dav-like Ctrl/Authority facet, lower-SES): "The advisor didn't say I have to take a prerequisite prior to these classes, so, do I register for them? Not sure."

On the other hand, higher-SES students' greater comfort with risks could incline them to be less cautious and bypass checking their progress:

> S1 (Fee-like TechRisk facet, higher-SES): "I already took them <(but doesn't look to see if the system knows this)>... I'll just <register for> my next class."

4.4 Bug #5: System missing progress information

Team R found Bug #5 when they realized that in some cases, the system's record of courses the student had taken before might be incomplete—or might at least *seem* incomplete to Dav. Team R noticed several places this bug could arise. Figure 13 shows Dav seeing an empty progress bar upon clicking on "View Your Progress". As Team R put it:

> Team R (eval. form): "It doesn't show his transfer credits, so he would be concerned because he isn't seeing any progress."

Results from Study 2 overwhelmingly confirmed Team R's observation. 10/12 interviewees across multiple universities reported having seen this bug. For example:

> I-X4: "The majority of the issues we're having with incoming transfer students ... attempting to register before their transfer credit has been completed."

> I-W1: "We've had students that say, hey, I took this at <prior institution>. Well, it was equated to something different. It may be Calculus 1, where you took it, but... we equated it to Trigonometry."

Bearing out Bug #5's prevalence, students in Study 3 encountered it 9 times. For example, Figure 14 shows S10's experience where S10 encountered a prerequisite-needed error when trying to register for a class they believed they had transfer credit for.

Team R had expected students with Dav-like Access to Reliable Technology to be particularly impacted, and that was true for 4/6 of the students experiencing it. But the same 4/6 of these students also had Dav-like Control/Authority facet values (Figure 15), which was particularly revealing for Bug #5. For example, consider the difference between S2's and S9's responses to experiencing Bug #5. S2, who had a Dav-like Control/Authority facet value, showed

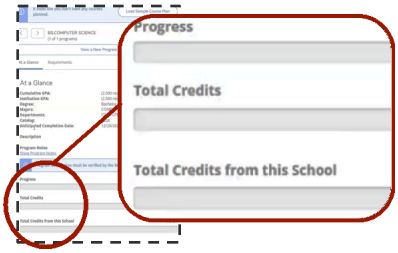

Figure 13: Bug #5: Screenshot from Study 1 SESMag walk-through, where Dav is looking at his progress, but his transfer credit is completely blank (callout).

no interest in working with an authority figure like an advisor to address Bug #5 (Figure 16(left)). Instead, they decided to do whatever they could within the confines of the interface:

> S2 (Dav-like Ctrl/Authority): "I'll try to go again to registering like I'll try to navigate. I'll try to see all of my options ... And if I feel as though, like, I already looked through everything on the website that was given to these students, and I can't figure out my problem. ..."

This is consistent with prior literature reporting low-SES students doing what they can without going to an authority figure, due in part to prior negative experiences from asking authority figures for help (e.g., [18, 35, 75]). For S2, if they could not alone resolve the problem, they elected to go to IT (who has no authority over them) ...

> S2 (Dav-like Ctrl/Authority), continues: "...I will try to probably call IT to ask them like how to navigate through the website..."

...rather than go to an authority figure like an advisor.
S9's response was the opposite of S2's. For S9 (Fee-like Ctrl/Authority), the way to resolve their missing credit seemed straightforward: enlist an authority figure (here, an advisor) to solve the problem (Figure 16(right)).

> S9 (Fee-like Ctrl/Authority): "...Maybe <I'll> meet with an advisor... It's not like I was going to give up after like this one failed attempt, I would still try to ask for help..."

Unfortunately, missing credit is not uncommon among transfer students. For example, a recent report of U.S. transfer students from 2-year colleges reports an average loss per student of 13 credits (about 1 semester's work and cost) due to the transfer, and that nearly 40% of such transfer students received no credit at all for their prior academic work [79].

4.5 How the facet values grouped by students' SES

As Section 2.1 explains, lower-SES individuals tend to have more Dav-like facet values, and higher-SES to have more Fee-like facet values. As Figure 17 shows, this was also the case with our study's students: the lower-SES students' facet values tended toward Dav-like facet values, and the higher-SES students' facet values tended toward Fee-like facet values. This distribution is consistent with the foundational literature surveyed in [17], and with the facet values empirically observed in [20].

5 Results: Downstream problems

RQ-Downstream investigates the downstream impacts that lower- vs. higher-SES students anticipated from SES-inclusivity bugs. To answer this question, we turned to students' responses to the post-think-aloud interview (Supplemental Documents) question #7: "Of these problems that you encountered... Do you think this is going to cause problems down the road? (EX: Does this mess up your scholarships, class prerequisites, etc.?)"

Figure 18 shows that 6/7 lower-SES students foresaw possible downstream problems (yes/maybe responses), compared to only 2/7 of the higher-SES students.

Lower-SES students foresaw downstream problems at three times the rate of higher-SES students. These students' main concerns were: (1) financial aid, (2) enrollment, and (3) employment. Financial aid could be especially important for lower-SES students who may struggle to attend university without it (recall from Section 1 that 78% of students at University X receive financial aid):

> Researcher: "So if you <don't> get into <needed> courses, would that affect ... anything?"
>
> S14 (lower-SES): "Yeah, most likely ... have to be attending full time for financial aid."

Students also foresaw impacts on their enrollment, which could further cause problems with their financial aid:

> S12 (lower-SES): "...it would affect ... being enrolled into the school. You'd have to re-enroll into the school if you didn't register for any courses during the term ... possibly affect your financial aid ..."

Moreover, students anticipated impacts on their jobs:

> S8 (lower-SES): "...<what> maybe impact me the most is the work schedule. Honestly, everything else I can deal with ... But work schedule? Yes, that can definitely be a big factor."

In contrast, the 5/7 higher-SES students that responded "no" to anticipating downstream problems saw these problems as being entirely within their control. For example:

> S4 (higher-SES), responding to the question about downstream problems: "... no."
>
> S4 (higher-SES) continues: "<address problems>...with planning and just knowing what you can and can't do, ... just you know, make time around whatever problems.... just plan around it."

Thus, not only did lower-SES students encounter more SES-inclusivity bugs (recall Section 4), but they also foresaw more problems downstream than higher-SES students.

6 Results: Registration Risks

6.1 The Risks

When Team R discussed the SES-Inclusivity bugs in Study 1, they expanded on possible "risks" for why students may not complete

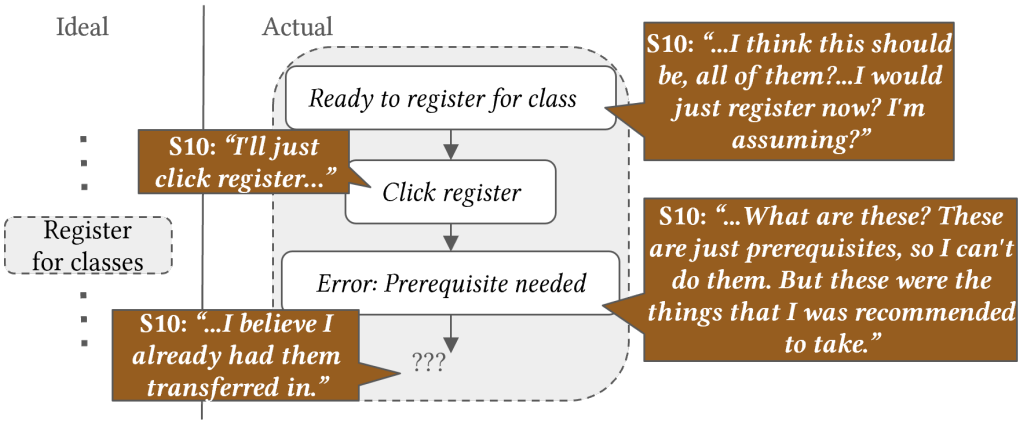

Figure 14: Bug #5: S10's experience trying to register for classes where S10 believes their credit has already transferred in but encounters a prerequisite-needed error.

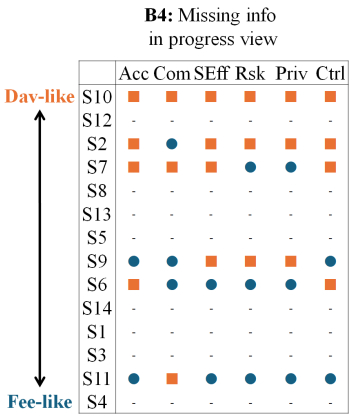

Figure 15: Bug #5: Facet values of students who experienced this bug. 4/6 students had Dav-like Ctrl/Authority. Colors: same as Figure 4.

each step of the registration process. Team R identified 5 risks, which then manifested in practice in Study 2 and/or Study 3 as shown in Figure 19. We denote these as "registration risks".

One example Team R identified during Study 1 was students missing emails containing advising instructions and directions to the registration portal (Reg. Risk #2).

> Team R (eval. form): "Our correspondence that goes out from the school at times is pretty lengthy... it goes out often, and so... <Dav> may not read the, the communications ... that may be too overwhelming..."

Interviewees in Study 2 confirmed 35 times in total that these risks had occurred with students across multiple universities (Figure 19). For example, Reg. Risk #2:

> Researcher: "have you ever seen or heard of a student who doesn't read the emails or communications sent to them?"
>
> I-V1: "Yes, absolutely... we try to send out information that's accessible and not overwhelming...there have been cases where students... have not checked."

... or solo registration, Reg. Risk #4:

> Researcher: "Have you ever seen a student just register by themselves? Without any help or, ...advice from a faculty advisor?"
>
> I-Y1: "Yeah, I've seen I've seen many cases of that..."

The effects of registration risks on student participants are shown in Figure 19 where students faced 4/5 of these risks in Study 3. Most common was Reg. Risk #2. As a case in point, Figure 20 shows University X's 47 emails to a student (not a participant in Study 3) about registration.

These emails pertain to Reg. Risk #2 because ineffective/unorganized communications can affect students during registration. And indeed, the student participants encountered this risk...

> S7: "...I need a little more communication back and forth. I had to email like three different people in different departments and kind of find out what was going on... there's no one around to help me out with where I need to go..."

Students also encountered other registration risks such as turning to peers instead of advisors (Reg. Risk #1)...

> S6: "I just kind of heard that from another student..."

...or having difficulty with unreliable technology (Reg. Risk #3[5])...

> S4: "I was trying to do it but... the audio on it was really bad."

...or trying to complete the registration process solo (Reg. Risk #4)...

[5]For the purposes of coding our Study 3 results, we updated Registration Risk#3 from "Lack of access to sufficient technology" to the more appropriate "Unreliable technology" because while all participants had *access* to the needed technology, some struggled with *reliability* of that technology (e.g., bad Wi-Fi).

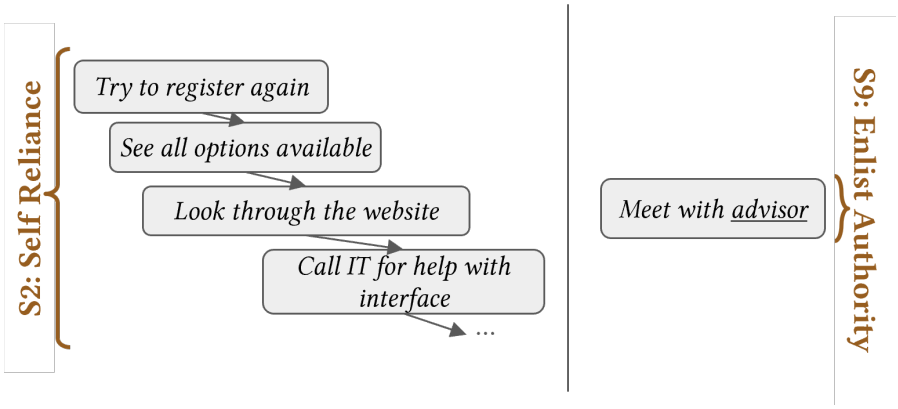

Figure 16: Bug #5, S2 vs. S9: Student S2 has Dav-like Ctrl/Authority whereas S9 has Fee-like Ctrl/Authority. To overcome Bug #5, S2 described trying to explore alternative solutions by themselves whereas S9 was opting for going directly to an advisor (authority figure) for help.

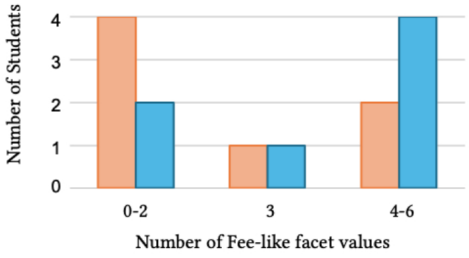

Figure 17: Study 3 participants' facet values (as per Section 3.3.2). X-axis's three categories: more like Dav (0-2 Fee-like facet values), halfway between Dav and Fee (3 Fee-like facet values) or more like Fee (4-6 Fee-like facet values). Y-axis: number of lower-SES (pale orange) and higher-SES (sky blue) students in these categories. 1 lower-SES and 1 higher-SES were halfway (3) between Dav and Fee., but most Dav-like students (0-2 category) were lower-SES (pale orange), and most Fee-like students (4-6 category) were higher-SES (sky blue).

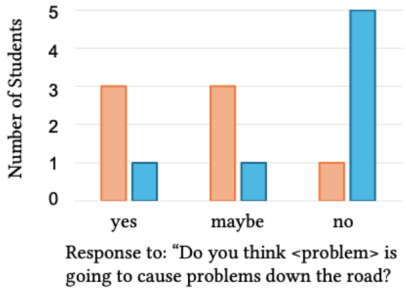

Figure 18: Students' responses to Question #7. The y-axis is the number of participants who responded with the values in the x-axis (yes, maybe, no). 6/7 of the lower-SES (pale orange) students described possible downstream problems arising from their difficulties with registration (yes/maybe), compared to only 2/7 of the higher-SES (sky blue) students.

> S14: "I already know how to register. The problem is I can't. I've done this whole thing before. I just can't register."

S14 (lower-SES) was the only student who faced Reg. Risk #4. Prior to meeting with an advisor they had attempted to register for classes by themselves but were unsuccessful. They then met with an advisor and joined our study.

Regarding Reg. Risk #5, Team R expected that students' previous registration experience could encourage students to register for classes on their own, possibly leading to problems down the road. Two of Study 2's interviewees confirmed having seen this. However, the risk did not arise with Study 3's students.

6.2 The Registration Risks and their conversion rate

These registration risks provide insight on why some students experienced SES-inclusivity bugs or downstream problems, as pointed out by Team R in Study 1 and confirmed by the interviewees in Study 2. Given this, it seems reasonable to expect a relationship: the higher the number of registration risks, the more SES-inclusivity bugs or downstream problems students should run into.

However, the opposite was true. As Figure 19 has already shown, lower-SES students experienced registration risks at half the rate of higher-SES students. The only exception was Reg. Risk #4 (solo registration), which one lower-SES student and no higher-SES students faced.

But the number of registration risks is not the entire story. Even though lower-SES students found ways to avoid or mitigate most of the registration risks, the "conversion rate" of these risks to downstream problems and/or bugs was much higher for them.

TEAM R		INTERVIEWEES												STUDENTS		
Study1: SESMag Walkthrough		Study2: Witnessed events												Study3: by SES		
		Registration Risks														
Registration Risks	Tied to which facet(s)?	I-X1	I-X2	I-X3	I-X4	I-X5	I-U1	I-V1	I-W1	I-Y1	I-Z1	I-A1	I-B1	Tot	Lower-SES	Higher-SES	Tot
Reg. Risk #1: Goes to peers instead of advisor	Comm.	✓		✓	✓	✓	✓	n/a	✓	✓		n/a	✓	8/10		✓	1
Reg. Risk #2: Ineffective/unorganized university communications	Comm.	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	11/12	✓✓✓	✓✓✓✓	7
Reg. Risk #3: Lack of access to sufficient tech	AccessReliable	✓	✓	✓		✓	✓							5/12		✓✓✓	3
Reg. Risk #4: Solo registration	AccessReliable	✓	✓	✓	✓	✓	✓	✓	✓	✓	n/a			9/11	✓		1
Reg. Risk #5: Problem due to prev. experience registering	None	✓	n/a	n/a		✓	n/a	n/a			n/a	n/a	n/a	2/5			0
Total		5	3	4	3	5	4	2	3	3	0	1	2	35	4	8	12

Figure 19: Results for each Registration risk over 3 studies.Study 1: Registration Risks and facets Team R tied to them. Study 2: Blank=no evidence from this source; n/a=not/applicable (interviewee did not answer this question); ☒=one instance of interviewees relating evidence of this registration risk. Study 3: Blank=no evidence from this source; ☒=one instance of a student running into this registration risk

Figure 20: Thumbnails of 47 emails sent to one student (identifying information blacked out out) between 04/2023 to 04/2024, containing instructions on registering/enrolling at University X. Yellow highlights show "registration" and "Registrar" words.

Table 3: The rate Reg. Risks converted into SES-inclusivity bugs &/or downstream problems (Downs) was 6.25/1.625=3.85 times higher for lower-SES than higher-SES students. Conversion Rate = *(#Downs+#Bugs)/#Reg.Risks*

	# Downstream Problems	# Bugs (Figure 3)	# Reg. Risks (Figure 19)	Conversion Rate
Lower-SES	6	19	4	6.250
Higher-SES	2	11	8	1.625

The "conversion rate" is calculated by the number of downstream problems and SES-inclusivity bugs that arose for students per registration risk. As Table 3 shows, lower-SES students' registration risks (4 instances) converted to SES-inclusivity bugs (19 instances) and/or downstream problems (6 instances) at a higher rate than for higher-SES students': for lower-SES students, each registration risk converted into 6.25 problems, while for higher-SES students, each registration risk converted into only 1.625 problems Thus, the registration risk problem ratio was over 3 times greater for lower-SES students than their peers.

7 Discussion

7.1 Discussion: why the conversion rate differences

One interpretation for the difference in conversion rates of students' registration risks between lower-SES students and their counterparts is differences in *empowerment*. Recall that definitions of SES consistently emphasize its connection to a person's access to resources and opportunities [91]. Few lower-SES individuals are in positions of power, and their low-power situations often necessitate compliance with the dictates of authority figures [36, 40, 51].

The Dav facet value for Control/Authority captures lower-SES individuals' awareness of this lack of power. Prior work has connected lower-SES individuals' perceived lack of control with a tendency to be accommodating to authority figures and to expect little help from them (e.g., [93, 96]). One recent study showed that lower-SES students were more likely to rely on themselves rather than asking for help, because of negative past experiences when asking for help led to being judged by teachers or peers [75].

But if a student does not seek help from advisors (authority figures) when registering, missteps can arise, such as missing prerequisites, registering for incorrect courses, or out-of-sequence courses that can increase time to graduate and overall costs—costs that may be impossible for lower-SES students to absorb. In contrast, higher-SES students can often afford to take more risks, like not seeking advisors, self-registering, not reading instructional emails, etc. Not only are they in a better socioeconomic position to bear extra costs, but also their (statistical) comfort level with authority means that if something goes astray, they are more likely to feel agency to address it (Control/Authority facet) by seeking assistance. For example:

> S6 (higher-SES): "...I also heard you can like email the instructor and see if they would take one more person,..."

A different authority figure is the university itself. In this role, the university sent communications requiring students to seek advising. But even when students attempted to comply, barriers arose preventing them from obtaining it:

> S14 (lower-SES): "...I was told my advisor was, like, three different people who weren't my advisor. And then they kept bouncing me around... I wasn't assigned to them, so they couldn't help me..."
>
> S9 (lower-SES): "...I'm trying to make appointments with my advisor. I'm emailing so many people because I don't know. like who my advisor is and who should I make my appointment with?..."
>
> S8 (lower-SES): "... the advisors were not, like, available like half the time. So I just took on my own hands..."

Even if these students had managed to obtain the advising they sought, Kwik et al. point to a related problem for CS transfer students: their concerns with the helpfulness of advising information they received [56].

The complexities between registration risks, barrages of complex instructions, less than supportive computer systems, power dynamics among human beings, students' facet values, and their socioeconomic constraints highlight the challenges a Registrar's office faces in achieving a smooth registration workflow. It is also an important one: as earlier work has shown, negative experiences during registration have a lasting impact on students' retention and overall academic outcomes [14, 68, 92].

7.2 How a university could address the inclusivity problems: Facets driving fixes

Chordia et al. point out in their review of HCI social justice research that the way a problem is framed "shifts *how* we pursue social justice" [22] (italics added). In Study 1, Team R framed the barriers around facet values, and as Guizani et al. explain in their Why/Where/Fix inclusivity debugging method [39], facet values provide foundational "why"s behind inclusivity bugs—i.e., "facets drive fixes" [20, 46]. For example, if an SES-inclusivity bug arises particularly with risk-averse students, that suggests fixing it by clarifying the risks explicitly or, even better, reducing the risks while clarifying them. Here, we consider potential fixes that the facet values behind the SES-inclusivity bugs can suggest to registration portal vendors and/or university Registrar offices.

Control/Authority Facet Value (Dav disproportionately impacted in Bug #1, Bug #3+4, Bug #5, as per Study 1 and/or Study 3): The Dav-like Control/Authority facet value's presence in some of the bugs and registration risks suggests solutions that could also help support Dav-like Communication facet values. For example, to address Bug #1 (Problems with advising), advising could be moved to a just-in-time chat—an "advisor in a button" staffed during certain business hours by advisor(s) from the student's own department. This change would make advisors much more accessible, potentially easing some students' reluctance to make appointments with an advisor (Control/Authority), easing communication difficulties some students may have in arranging such appointments, and helping students resolve conflicts between different authorities (Advisor's advice vs. the registration portal's options it gives to the student). Another possible solution that avoids authority figures entirely could be a *peer*-advisor capability linked to the registration portal; the PeerConnect system [7] offers an example of what this kind of system might look like.

Communications Facet Value (Dav disproportionately impacted in Bug #1, Bug #2, Bug #3+4, Reg. Risk #1, Reg. Risk #2 as per Study 1 and/or Study 3): The Dav-like Communication facet figured prominently in several bugs and risks in ways frequently tied with the university's numerous and often-complex emails (recall Figure 20). To improve support for this facet value, some of the email volume could be replaced by a dedicated page with standard instructions, available throughout the registration portal via both context-sensitive links and a search feature. Not only could this reduce students' email overload, it could also ease students' ability to re-find the right information exactly when they needed it.

Self-Efficacy Facet (Dav disproportionately impacted in Bug #1, Bug #2, Bug #5 as per Study 1 and/or Study 3): Other facets deepen the picture. The Dav-like Self-Efficacy facet value, though not emphasized earlier, can compound the impact of SES-inclusivity bugs. Lower self-efficacy reduces persistence in the face of adversity, whereas succeeding at a challenging task increases it [9]. The sociotechnical advisor-in-a-button solution could directly support

	Team R	INTERVIEWEES												STUDENTS			
	Study1: SESMag	Study2: Witnessed events												Study3: by SES		Study3: by facets	
		# SES-incl. bugs/reg. risks												# SES-incl. bugs/reg. risks Students faced			
	Team R	I-X1	I-X2	I-X3	I-X4	I-X5	I-U1	I-V1	I-W1	I-Y1	I-Z1	I-A1	I-B1	Lower-SES	Higher-SES	Dav-like	
RQ-SES: Bugs? yes	# SES-incl. bugs: ✓✓✓✓✓	✓✓	✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓	✓✓	✓✓	✓✓✓✓✓✓✓	✓✓✓✓✓	n/a	71
		✓		✓✓	✓	✓✓			✓✓	✓		✓✓	✓	✓✓✓✓✓✓✓	✓✓✓✓✓		
				✓					✓					✓✓✓✓✓	✓		
RQ-SES: Risks? yes	#risks: ✓✓✓✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓		✓	✓✓	✓✓✓✓	✓✓✓✓	n/a	52
		✓✓	✓	✓✓	✓	✓✓	✓✓		✓	✓					✓✓✓		
		✓				✓											
RQ-Facets	AccessReliable: ✓	n/a												n/a		✓✓✓✓✓✓✓✓✓✓✓✓	41
	Comm.: ✓															✓✓✓✓✓✓✓✓	
	Self-Efficacy: ✓																
	TechRisk: ✓															✓✓✓✓✓	
	Priv/Sec:															n/a	
	Ctrl/Authority: ✓															✓✓✓✓✓✓✓✓✓✓	
RQ-Downstream ? yes	n/a	n/a												✓✓✓✓✓✓	✓✓	n/a	8

Figure 21: All RQ results are triangulated by multiple occurrences in multiple studies. RQ-SES ✓:(for Study 1): one instance of Team R finding a SES-incl. bug/reg. risk. (for Study 2): one instance of interviewees relating evidence of a SES-incl. bug/reg. risk. (for Study 3): one instance of a student facing SES-incl. bugs/reg. risk identified by Team R. RQ-Facets ✓: (for Study 1): one instance of a facet Team R associated with an SES-incl. bugs. (for Study 3): one instance of a student facing SES-incl. bugs/reg. risks identified by Team R. RQ-Downstream ✓: (for Study 3): one [yes/maybe/no] instance of a lower- or higher-SES student noting potential downstream problems from the inclusivity bugs they faced in registering. n/a : data not applicable to this RQ.Blank: no evidence

this by empowering students, when collaborating with the advisor, to turn registration roadblocks into solved problems, an approach aligned with the growth mindset interventions in other settings (e.g., [8, 24, 109]). Walton et al. further suggest that this kind of support, even before classes begin, can increase sense of belonging, improve retention, and reduce postsecondary inequity [100]. The registration portal could further reinforce the student's growth mindset and increase their self-efficacy [9] by enabling students to explicitly list registration roadblocks as they arise, and then check them off as they solve them.

Other facet-based solutions (Dav' other facets disproportionately impacted in Bug #1, Bug #2, Bug #5, Reg. Risk #3 and Reg. Risk #4 as per Study 1 and/or Study 3)*:* In addition, several facet values point to more solutions to address the SES-inclusivity bugs. For example, Access to Reliable Technology (including Internet access) suggests a simple, yet powerful solution—a save button at the bottom of every step—so if students get disconnected or run into errors, it doesn't erase progress, and students can continue later where they left off. For Self-Efficacy, small interface improvements can matter: a progress bar or checklist that shows they are making progress can boost confidence. In addition, a navigation bar that allows students to navigate to any step in any sequence, with % complete shown next to each step, would give students the agency to select the registration steps in any order needed, which may especially help students resume at the right place when unreliable internet access disconnects them.

Recall that University X uses a commercial registration portal that is also used by over 700 other universities around the world. Fixes like these could potentially impact hundreds of thousands of university students.

7.3 Triangulation

One way to ensure rigor in qualitative studies is triangulation—viewing findings from multiple angles and from multiple points of view [110]. Triangulation is used both to safeguard against threats to construct validity and to add confidence to the results. Thus, to ensure reliability in our trio of qualitative studies we included extensive triangulation.

Figure 21 shows our triangulation from multiple evidence sources for all three studies. As the table shows, 71 sources of evidence cross-confirmed *RQ-SES's* results about SES-inclusivity bugs, 52 sources of evidence cross-confirmed *RQ-SES*'s results about Reg. Risks, 41 cross-confirmed *RQ-Facets*' results, and 8 cross-confirmed *RQ-Downstream* results.

7.4 Limitations

Every empirical investigation has limitations, and ours is no exception. Of particular note in our investigation is lack of controls, as is common in case studies that investigate situations in their real-world contexts [110]. For example, each student's activities were different; they chose courses according to their own particular background, they registered from different locations at different times of day, used their own devices, and did whatever they did with the advice that had just been given to them by whatever CS advisor they used. Some students could have been distracted by the need to keep talking aloud while also registering. Given this

lack of controls, we safeguarded our within-study analyses with inter-reliability measures [89] (as described earlier in Section 3), and cross-checked both our within-study and between-study results using extensive triangulation, as detailed in Section 7.3.

The SES-inclusivity bugs and registration risks identified in Study #1 were the work of Team R, and that team's makeup was also not controlled. Its members were chosen by the Registrar's office, and its outcomes are dependent on its membership. That said, the SESMag method they followed uses a cognitive walkthrough, and as Mahatody's survey has shown, members of the cognitive walkthrough family have all been shown to be at least 90% accurate in terms of true positives (i.e., producing fewer than 10% false positives) [60]. (SESMag's sibling, GenderMag, also has averaged 90-95% true positives [16, 39, 98].) All SES-inclusivity bugs and registration risks were then validated by Study 2 and all but one again in Study 3, providing extensive substantiation of the soundness of Study 1's results. However, Team R's results probably were not complete, as false negatives are common with cognitive walkthroughs [60]. It is especially likely to be incomplete because Team R used only "Dav," which considers only one end of the SES spectrum. They might have found additional SES-inclusivity bugs and/or registration risks if they had also used "Fee" to also consider the other end of the SES spectrum.

Another limitation is that these students were CS students, who may have interacted with the registration portal differently than other students would do. As such, this research offers a conservative view of the SES-inclusivity bugs and registration risks that college students can run into. That is, CS college students may offer a "best-case" look at the ease of registering for classes, and other students may run into more. However, some researchers suggest that CS transfer students may experience even greater challenges than other majors [56].

Limitations could also have arisen due to potential conflicts of interest (COIs) arising because the investigation occurred within a single university. Four such potential COIs and the measures we took to mitigate them were:

- Potential COI: The registrar staff could have wanted students to give favorable feedback on the registration system at University X. Mitigation: Our investigation's methodology did not enable registrar staff to have any influence over which students we recruited or how students behaved during the investigation.
- Potential COI: University X could have wanted interviewees to deny that Study 1's issues ever arose. Mitigation: Only 5 of the 12 interviewees were affiliated with University X, and those 5 interviewees collectively verified all the issues. The other 7 non-X interviewees likewise collectively verified all the issues independently.
- Potential COI: University X could have wanted to bias data analysis to influence the results. Mitigation: All data analysis was done at the partner research university.
- Potential COI: University X could have wanted to gain financially from the results. Mitigation: There was no financial advantage to University X or to the researchers or administrators tied to finding registration issues.

Finally, as in all empirical case studies, the results of Study 1 and Study 3 are not meant to generalize to populations/universes, but rather to investigate how some theoretical framework applies to real-world phenomena as they arose in a real-world context [110]. For our investigation, Study 1 investigated the real-world phenomenon of college professionals using SocioeconomicMag to find sociotechnical SES-inclusivity bugs in this context, and Study 3 investigated how these SES-inclusivity bugs actually arose with students in the same context. To add generality, we triangulated University X's SES-inclusivity bug results with Study 2's interviews, which covered 8 universities in total who use the same registration portal. Further investigation of the generality of our findings would require additional empirical studies in additional contexts.

8 Conclusion

A largely unstudied aspect of higher education is what happens between the time a student decides to attend college and the time they attend their first class, and whether particular groups of students are disadvantaged during that time.

> S14 (lower-SES): "have to be attending full time for financial aid"
>
> S12 (lower-SES): "I'm stuck…the classes I'm trying to register for, I can't because of a blockage"
>
> S14 (lower-SES): "I just wanted to get … someone from the school to kind of put me in the right direction…"

The group we investigated is lower-SES CS transfer students, and in this paper, we present a three-study empirical investigation into the sociotechnical registration process that these students experienced in transferring to University X. This is the first field study to investigate SES-inequities faced by SES-diverse transfer students performed by college professionals using the emerging SocioeconomicMag method.

Our results revealed 5 SES-inclusivity bugs, 5 registration risks, and 3 downstream problems, almost all of which had disproportionate impacts depending on the student's SES. Specifically:

- SES-Inclusivity Bugs: Students experienced the SES-inclusivity bugs 30 times. Lower-SES students experienced these bugs 72% more often than higher-SES students (Section 4).
- Registration Risks by SES: Unexpectedly, lower-SES students faced registration risks only half as often as higher-SES students. But when these risks arose, they spawned SES-inclusivity bugs or downstream problems over three times as often as for higher-SES students (Section 6).
- Downstream problems by SES: The lower-SES students in our study anticipated these SES-inclusivity bugs they experienced to escalate into serious problems more often than the higher-SES students did. The types of problems they worried about included (1) losing their financial aid, (2) being disenrolled from the university due to registering for too few classes, and/or (3) producing unresolvable conflicts with their outside job (Section 5).

Given these results, the answer to our investigation's central research question—"Are registration processes equitable for students across diverse socioeconomic statuses?"—appears to be no, at least

for our study's SES-diverse CS transfer students. Fortunately, our results also show that these SES-inclusivity bugs and registration risks were discoverable using the SESMag analytical method. Section 7.2 discusses how some of these inclusivity bugs have potential sociotechnical fixes involving process changes and/or changes to registration portal itself, which is currently in use by over 700 colleges and universities. We hope Registrar offices and registration portal vendors work together to try fixes like those in Section 7.2, potentially improving the registration experiences of hundreds of thousands of computing students.

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