Introductory Engineering Courses With Computational Thinking: The Impact of Educational Privilege and Engineering Major Entry Policy on Student Pathways

Noemi V. Mendoza Diaz
Dept. of Engineering Technology and Industrial Distribution
Texas A&M University
College Station, TX, USA
nmendoza@tamu.edu

Deborah A. Trytten
School of Computer Science
University of Oklahoma
Norman, OK, USA
dtrytten@ou.edu

Russ Meier
Dept. of Electrical Engineering and Computer Science
Milwaukee School of Engineering
Milwaukee, WI, USA
meier@msoe.edu

***Abstract*— This research category paper examines the impact of computational thinking within first-year engineering courses on student pathways into engineering. Computational thinking and programming appear in many introductory engineering courses. Prior work found that early computational thinking development is critical to the formation of engineers. This qualitative research paper extends the research by documenting how pre-university privileges impact first-year student trajectories into engineering through a qualitative examination of student interviews from three institutions with different processes for matriculation into engineering majors. We identify the underlying assumptions of meritocracy that are concealing the role of educational privilege in selecting which engineering students will be allowed to join the field. We provide a suggestion for how institutions can include computational thinking in introductory engineering courses with less risk of furthering the marginalization of students with few academic privileges.**

Keywords—diversity, computational thinking, first year curriculum, persistence, matriculation

I. Introduction

Entry into an engineering major is a filtering process of determining who is and who is not "good enough" to become an engineer. Academic institutions are presented with challenges when more admitted students want to participate in engineering programs than can be served. The choices that are made in selecting which students will be permitted to participate in the program has broad implications on who gets the opportunity to be an engineer and who is forced to switch to other majors.

General introduction to engineering courses have been studied quantitatively, with much of the data coming from the MIDFIELD database. Introduction to engineering courses have been found to help students find and join lesser known engineering majors [1], and to increase student retention [2].

The first two years in an engineering curriculum are when most attrition occurs, making this a critical time to examine every aspect of the process of matriculation into engineering [3]. Chen et. al. created a taxonomy of the ways in which programs allow students to enter engineering majors [4]. The salient parts of the taxonomy for this work are whether the students matriculate directly to a major (DM), are required to join a structured first year engineering (FYE) program before selecting a major, or required to have another major prior to majoring in engineering (PM, for pre-major). The DM and PM categories are further decomposed by whether all engineering students are required to take a specific engineering class (a, for all) in their first term or whether this requirement exists for only a subset of majors (p, for partial). The PM category also has a grouping for students who do not take an engineering course in their first term (o, for without).

A factor that impacts the admission and success of students in engineering programs is Advanced Placement (AP). In the US, students can get college credit for pre-university academic coursework by passing nationally normed examinations given by the College Board (a non-governmental non-profit corporation). Large and well-funded schools have as many as 38 AP courses [5]. Rural and small school districts often have fewer AP courses [6] [7] [8]. Other schools have none. Taking AP examinations is expensive (currently between \$96 and \$126) [9]. Cost can preclude students with limited financial resources from taking the examinations and may discourage students from low socio-economic statuses from taking AP classes, especially those that are uncertain college attendance will be possible. In the US, 52% of children are classified as low income. Among AP exam takers, 30.1% were low income. Among AP exam takers who scored a 3 or better, equivalent to a low B (3.0/4.0) or C (2.0/4.0), only 24.9% were low income [6] [10]. The College Board, perhaps tellingly, does not publish the data about how many low income students earn a 4 or 5 on AP exams. Students in resource-poor urban schools also have limited success with AP [11].

A multi-institutional research team is exploring how computational thinking in first-year engineering courses impacts student enculturation into the engineering profession. Previous publications document development and validation of a survey instrument called the Engineering Computational Thinking

Diagnostic (ECTD), application of the survey, and initial findings from semi-structured interviews describing the impact of privilege on student trajectories [12] [13] [14] [15]. In a new phase of the research plan, semi-structured interviews were performed with larger cohorts at three institutions to validate and extend the previous work. The semi-structured interviews and data analysis investigated this research question:

- In what ways does stress caused by computational thinking coursework impact student confidence during first-year engineering experiences?

We were initially looking for patterns of student success and confidence by social identity but instead found the impact of privilege and meritocracy, beyond just the area of computational thinking. We documented meritocracy hurting people with systemically marginalized social identities.

II. POSITIONALITY STATEMENTS

Noemi Mendoza Diaz is a Hispanic female assistant professor of engineering technology and industrial distribution at a large, public university, whose view of racial and ethnic minorities are influenced by her ethnicity. Deborah Trytten is a white female professor of computer science at a medium sized public university. The first two authors both came from educationally privileged middle-class backgrounds. Russ Meier is a white male professor of computer engineering at a small private technical institution. He grew up on a Sioux Indian reservation and was the first generation in his family to attend college. Other aspects of our positionality and our efforts to maintain research quality in the presence of our positionalities have been published [15].

III. METHODOLOGY

This qualitative work builds on quantitative work done creating and validating the ECTD [12] [13] [14]. After approval by an Institutional Review Board, the ECTD survey was administered to students in introductory engineering classes with a programming or computational thinking component at a small private northern university (NU), a medium-size public flagship midwestern university (MWU), and a large public southwestern land grant flagship university (SWU). Table 1 shows classifications from the Carnegie Classification of Institutions of Higher Education [16].

TABLE I. INSTITUTIONAL CARNEGIE CLASSIFICATIONS

Undergraduate Profile Classifications		
NU	***MWU***	***SWU***
Four year	Four year	Four year
Full time	Full time	Full time
More selective	Selective	More selective
Low transfer In	Low transfer in	High transfer In
Enrollment Profile		
NU	***MWU***	***SWU***
Very high undergraduate	High undergraduate	High undergraduate
Basic Classification		
NU	***MWU***	***SWU***
Master’s medium (M2)	High research (R1)	High research (R1)

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TABLE II. UNIVERSITY ADMISSIONS REQUIREMENTS

NU			MWU	SWU
Criterion	***Required***	***Recommended***	Holistic	Holistic
GPA of 3.0/4.0	X			
ACT/SAT Scores	X			
Pre-calculus math	X			
Four years math		X		
Four years science		X		
Chemistry		X		
Physics		X		
Four years English		X		

Table II documents engineering admissions requirements at the three universities. MWU and SWU use holistic admission processes where factors beyond standardized tests, secondary school course grades, and secondary school GPA are considered during admissions decisions [17]. At NU, public statements reflect use of performance in preparatory coursework as well as historic use of standardized test scores, although ACT/SAT score requirements were suspended in COVID-19 pandemic years.

Students at all three institutions were enrolled in a first-year level class that included computational thinking. At NU, participants were recruited from introduction to programming classes for software engineering, computer engineering, computer science, electrical engineering, biomedical engineering, and user experience majors. At MWU, participants were recruited from classes that teach programming in a variety of languages. The programming classes are required for industrial engineering, computer engineering, computer science, and electrical engineering majors. All three classes are taken by a variety of other majors, including those outside of engineering, although not necessarily in the first year of their degree program. At SWU the class was an introduction to engineering class taken by all engineering majors that had a substantial amount of computer programming.

We asked ECTD survey participants about their confidence in becoming professionals in engineering or computing both at the start of the term and shortly after a major assignment had been due. We calculated differences between their reported confidence values to identify students who were gaining, maintaining, and losing confidence as the term progressed. We invited students from all three categories to interview, although we had difficulty recruiting participants with low or decreasing confidence. As a result, most participants were quite confident and had steady or increasing confidence. Participants were paid $25 for completing the interview, to compensate for their time.

Interviews were done by four interviewers working from the same semi-structured protocol using teleconferencing software. The protocol was an improved version of a previous protocol that addressed the student’s secondary school and first year college experiences in engineering [15]. Interviews usually lasted about 20 minutes. The interviews were automatically transcribed by the teleconferencing software, hand edited by research assistants, and verified by a second research assistant.

The interviewers all agreed that we were far beyond data saturation at NU and SWU, and considered early termination of interviews [18]. We continued with interviews because participants were compensated for their time, and we felt it was disrespectful of participants to cancel abruptly. At MWU, some of the students who were interviewed were not engineering majors. As their experience was not relevant to the research question, we removed these interviews from this analysis. In addition, one of the interviews at MWU was not able to be transcribed due to poor quality audio and was also removed from analysis. As a result, we do not claim data saturation at MWU. The number of participants from each institution by some self-selected social identity characteristics is given in Table III, as suggested as a best practice [19].

TABLE III. PARTICIPANT DEMOGRAPHICS

Category	Subgroup	NU	MWU	SWU	Total
Gender	Female	4	8	5	17
	Male	10	5	13	28
	Preferred not to say	-	1	-	1
Ethnicity	Hispanic	-	2	6	8
Race	Asian	-	2	6	8
	AI/AN*	-	1	-	1
	Black	-	-	1	1
	White	14	11	10	35
	Multiracial	-	-	-	-
Grand Total		14	14	18	46
Removed		-	7	-	7
* AI/AN = American Indian/Alaskan Native					

The interview transcripts were coded using qualitative data analysis software. The coding process started with the codebook from previous work [15]. Codes were added, refined, and merged during analysis, using an iterative and inductive process [20]. The final codebook was therefore larger and more nuanced than the original codebook.

Coding was performed by a single researcher (DAT), using a dense coding strategy like the open coding used in ethnography [21]. Using this strategy, passages were coded in all relevant categories to reflect the many intersecting topics that students discussed. The researcher coded the transcripts in full paragraphs, including both interviewer questions and participant responses, to retain critical context and avoid misrepresenting participant contributions.

Searches of nodes were done broadly to make sure that all transcripts that addressed an issue were considered during the analysis. The combination of dense coding and broad searching increases dependability of the interpretation of the data, at the expense of more time-consuming analysis since the number of passages that are examined is increased.

The mechanisms to ensure trustworthiness in this investigation consisted of prolonged engagement, peer-debriefing, and audit trails. No interviewer interacted with students at their home institution. After multiple years of research at these institutions, interviewers have experienced each institution's culture and this cultural knowledge was shared during research meetings. Peer-debriefing occurred during the weekly meetings of the research group where the analysis of ideas and interpretations were discussed and contrasted. The researchers kept minutes of all these discussions and referred to those whenever pertinent. Transferability, understood as the "researchers' responsibility to provide the data base that makes transferability judgements possible on the part of the potential appliers", was assured by describing the relevant institutional characteristics and introductory engineering approaches in as full detail as possible without identifying the institutions where interviews took place [22].

The following conventions are used to quote participants. Statements made by the interviewer are preceded by an I:. Statements made by the participant are preceded by a P:. Words that are removed or modified to protect the privacy of the participant are enclosed in square brackets []. Words added by the researchers to clarify the context are between curly braces {}. The best guess at words that could not clearly be transcribed are recorded in parentheses (). Ellipses are used to indicate that parts of the participant's response that are not relevant to the discussion have been removed. Although this practice is not without controversy [23], quotes were edited to remove verbal ticks (such as the frequent use of "yeah" and "like") and to increase readability without altering meaning. This editing is done since transferring spoken English directly to text can make participants sound less thoughtful and articulate than they are, which unfairly represents the participants. Participants will be referred to using they/their pronouns, as we failed to collect preferred pronouns from participants. Some participants talk about "high school." This is the common US term for the secondary education years also called pre-university.

IV. RESULTS

Each of the institutions has a different process for admitting students to engineering majors. Institutional admission practices were retrieved from public institutional websites and all information was verified by an engineering faculty member employed by the institution for accuracy.

First-year students at NU are directly admitted to their engineering major of choice, and begin in-major coursework immediately. This matriculation technique is an example of the DMa category in the engineering matriculation taxonomy [4].

All first-year students at MWU are initially admitted to a generic college. After students have one year of college courses, they are allowed to change to specific engineering majors without an application process. This transfers the student from the generic college to the College of Engineering. All but two engineering majors are open to all students who are in good standing and have a 2.0 grade point average (at all three institutions, this GPA is scored out of 4.0). The two majors with enrollment restrictions control entry to these majors using college GPA after Calculus I and II, physics, chemistry, and 24 hours of college-level work are completed. The GPA threshold for these two majors is 3.0 and is published in advance. Students in these two majors rarely take the introductory programming classes where we recruited participants. This puts MWU in the PMa category in the engineering matriculation taxonomy [4].

First-year engineering students at SWU initially enroll as a general engineering major. After their first year of college, consisting of engineering, science, and math classes, they apply to their major(s) of choice, listing up to five choices. The admission process places students in their highest ranked major possible based on academic performance, content in the application, and program's capacity. A cumulative GPA of 3.75 is used for automatic admission to any engineering major. SWU is a FYE in the engineering matriculation taxonomy [4].

The competition for entry into majors at SWU can feel intense to first-year engineering students. Students are understandably fixated on meeting the GPA thresholds for automatic admission to their major. Every participant who reported stress from the need to maintain a high GPA was enrolled at SWU. Unsurprisingly, more than half of the SWU participants reported experiencing at least some grade stress.

> I: *Where are you going?*
>
> P: *I'm hoping to get into {computer science}.*
>
> I: *Do you expect that to be successful?*
>
> P: *Well, we still don't know yet. It still depends at the end of the day on the GPA. I sure hope so but there is no certainty.*
>
> I: *Is that the only factor used in the decision?*
>
> P: *If you are not auto-admitted it is very, very unlikely that you get in. I guess it's not the only factor, but it is the biggest factor.*
>
> *SWU Student*

Students at SWU obsessively attend to their GPAs. When the interviewer attempted to point out that a single B might not reduce their GPA below 3.75, the participant responded with their detailed mathematical analysis and their belief that hard work is all that is required to excel in engineering.

> I: *...So how do you feel confidence wise?*
>
> P: *Well, to be able to be guaranteed a slot in my preferred majors and minors, I have to have at least a 3.75 {GPA}. ...It is high, but everyone wants to be in aerospace. It's competitive, so (long pause) I'm confident that I can get a 4.0 or whatever. But you know, there's still just a little bit, a little bit of anxiety that you mess up once {and} you've got to replan your whole future.*
>
> I: *So you might want to do that math a little more carefully because you could get a B and still have a 3.75 GPA.*
>
> P: *Yes, but only in certain classes. There's some classes I'm taking that are four or five credits that I cannot get a B in.*
>
> I: *You've done the math.*
>
> P: *Yes, I have done the math (laughs). So it depends. All the hard classes I cannot get a B in. ...But I'm very confident. I think I can definitely do it if I put my mind to it. Just about working hard, I guess. If you're struggling, you just got to put a little more time into it.*
>
> *SWU Student*

A participant who was becoming less confident in their ability to pursue computer science at SWU expressed their concerns about being accepted into this major. They had a misunderstanding of the format of the first exam in the introductory engineering course and had a low score.

> I: *...How do you feel your confidence is right now about being able to pursue computer science here at [SWU]?*
>
> P: *I'm not so confident right now because I took my engineering exam for computer science, and it was not what I expected so it kind of brought my confidence level down.*
>
> I: *...Are you going to have another exam?*
>
> P: *Yes, I'm going to have a second exam.*
>
> I: *How are you feeling about that?*
>
> P: *A little worried.*
>
> I: *How do you think this engineering course is impacting your desire to remain as a computer scientist?*
>
> P: *Now, I feel like I see that computer science is more challenging than I expected. I have my doubts about if I will be able to get into computer science now because I see how difficult it really is.*
>
> *SWU Student*

Some students reported going to great lengths to implement strategies they thought would improve their chances of being auto-admitted to their chosen major. The participant below used AP credits to avoid taking the harder Calculus 2 yet chose to take Calculus 1 to boost their GPA.

> I: *Did you take the [AP Calculus 2] test?*
>
> P: *Yes*
>
> I: *Did you remember the score you got on it?*
>
> P: *Yeah, I got a 5. {the highest grade possible}*
>
> I: *Does that mean at [SWU] you are not in Calculus 1 right now?*
>
> P: *I'm taking Calculus 1 but I skipped Calculus 2. ...*
>
> I: *Okay. Why did you make that decision?*
>
> P: *I was honestly pretty intimidated by the entry-to-a-major process here. I'm not sure, I probably could have skipped [Calculus 1] now that I think about it, but I also heard a lot of rumors and stuff that they have a particularly hard [Calculus 2] here. I just didn't want to deal with that. Next [term] I'm taking linear algebra instead of the typical [Calculus 2].*
>
> I: *...What did you mean when you said you were intimidated by the entry-to-major process?*
>
> P: *I just felt that it was very possible that if I took much harder courses, courses that would actually be a challenge to me, it was very possible I could get B's and C's in them ... I felt like it's not very competitive for me to do a bunch of really hard stuff straight out the gate.*
>
> *SWU Student*

This participant appears to understand "competition" to include cleverly leveraging AP credit for Calculus 1 and 2 to bolster their chances of entry into their chosen major. This competition is being played on an unlevel field.

A less financially privileged student at SWU is unable to pursue strategies like this, because it increases the cost of college. The verbal non-fluencies, that normally would have been removed, were retained because they are indicative of the stress this student is experiencing in talking about this subject. The student reported that they were passing Calculus 1 earlier.

> I: *...What do you think happened here?*

P: *I don't I don't know what to say, because the classes that I'm taking right now, it's it's literally the same class that I was like in high school, but it's just a lot. It's just a lot. I just don't, I'm just not doing much better. I'm not doing. I'm not doing good at all, I guess.*

I: *Ok. When you compare yourself to other students, what's your observation?*

P: *Well, in that class, I'm with a bunch of sophomores who either took the class already or they took calc 1 in the last [term]…They said that if you don't take calc 1 here at [SWU], you would have a hard time. Well, it's true. That's a fact. So yeah, I don't know. I don't know how I'm able to compare myself as a as a freshman who took who took calc 1 in the different in a different institution, you know, to students who took it here. So I guess I'm at a disadvantage.*

I: *So do you wish you had taken {Calculus} 1 instead of {Calculus} 2?*

P: *…No. I already took {Calculus} 1. I have a credit for that and I really don't want to pay for that again because I'm I am paying for my own college and rent. So that's how I build up a lot more stress, too.*

SWU Student

AP credit is an educational privilege. College credits earned in secondary school are especially valuable in engineering because many majors require more than the institutional minimum number of credits to graduate. A student with AP credit has curricular breathing room that those without AP credit don't. This can translate into the ability to take a minor or second major of interest, early graduation (with substantial monetary savings), or lower credit loads each term. In addition, AP credits are often seen as a positive factor in many college admissions decisions and when selecting scholarship recipients [6]. AP courses, whether students receive college credit or not, can help prepare students for college level work while they are in secondary school. AP credits are a privilege that tends to support more privileges. Recent work has shown that engineering students with AP credit have GPAs that are 0.22 units higher than those who do not have AP credit [24]. When considering SWU's stringent GPA requirements for auto-admission, this difference is critically important.

The participant below knows that their AP credit has made their pathway in engineering easier. The AP examinations in physics are not calculus-based, and are generally not equivalent to the physics classes that engineers take in college, although they do provide background in a topic that many engineering students find challenging.

I: *So how about science classes? Have you taken any of those {in college}?*

P: *I have. I took chemistry first [term] last year. I took physics {1} in the [term] of last year. I'll be taking physics 2 in the [term]. Yes. What did you ask about those?*

I: *…How are they impacting your confidence?*

P: *I wouldn't say they have any tremendous impact on my confidence. {pause} I mean, they were both relatively easy because it was part recap from high school, I took AP Physics 1 and 2 in high school. So.*

NU Student

The participant below started their college mathematics in differential equations and is now benefitting from the accumulation of privileges. They have already been hired, as a first-year student, for a prestigious internship at a major technology company. This cascade of privileges is likely to continue.

I: *So in what ways do you feel like an engineering and computing professional?*

P: *I'm good at it math and science and computer science. So I'm confident enough in my skills that I feel like that helps me feel like a professional in that field. Plus, I have gone to a career fairs and interviewed then and got offers, and it's like assured me that I'm doing the right thing.*

I: *So tell me about those offers.*

P: *Well, I applied to a lot of companies. I got three final round interviews. I haven't. I mean, I haven't {heard} back from other companies because I withdrew applications because I got an offer that I accepted, but I got a final round offer from [popular technology company]. I didn't get to interview with them because I accepted from [another popular technology company] and then got an offer from an oil and gas company.*

SWU Student

Beyond AP credits, the number and breadth of the other educational privileges that some participants reported enjoying was staggering. The participant below, in spite of their claims of being an amateur, had a substantial programming background.

I: *Tell me a little bit about your computing background before you came to [SWU]…Did you have any computing experience before you came to the university?*

P: *Yeah, around ninth grade I took a visual coding, it was kind of similar to [language] if you are familiar. It wasn't actual coding, but it definitely taught me a lot about algorithms and stuff like that. Then in high school I took a computer science course like every year. We had three levels of computer science, so computer science 1, 2, and 3. I took that my sophomore, junior, and senior year. They offered AP courses for CS, but I never took them. Over the pandemic I got into competitive programming. I'm pretty amateur.*

SWU Student

The participant below had the benefit of coding camps and tech classes in secondary school, and now has soaring confidence.

I: *…Is there anything else that you would like to add that you think might be valuable for this study on how to get in and remain in computing?*

P: *…When first stepping into learning about the field and hearing about what everybody's talking about, I'm hearing about these higher-level classes like data structures and like embedded circuits and embedded systems and stuff like that, where it's all these really advanced things and building your own like central processing unit on your own CPU and stuff like that. It sounds insanely daunting and almost seems like I will never be able to get there. But now, after being in school for two months now, It's obviously not even like it's a very small fraction of my college career. I feel like it's doable because of everything now that I'm learning about my career is just going to build on top of each other until I can get to that point where I can sort of view those daunting tasks. And* *you're also not expected to know everything going in. That was something that definitely terrified me going into college was that, I thought I was expected to know everything about the field before I went to college, but and so that's why I took a lot of like tech classes in high school, that's why I went to coding camps during my high school career as well, is that like I thought I needed to know coding before I decided to go into college to learn more coding. And that's not actually true. It's like everything is presented to you in a way that you will be able to, you know, progress at a steady pace.*

NU Student

An especially important privilege is prior programming experience in secondary school, as demonstrated by our previous work [15].

I: ...if you look at this introductory engineering course that you're in right now, how does it make you think about your future as an engineer?, your plans for engineering? It is it reinforcing those? Are you questioning it in any way?

P: It's neater because this is an introductory [language] course, which I already know all of the content. So it's not really like challenging my beliefs or reinforcing any ways.

SWU Student

A student without prior programming experience, also sees the advantage of this experience. This student was from NU, and therefore already admitted to their major and not reporting grade stress.

I: So how do you feel your confidence has changed now that the {term} has gotten rolling?

P: In the beginning, I was very confident. But then… I saw our classmates very like actively coding for years, since they were 14 and 15, and so it was just a wakeup call, I guess you could say. How some people were completely advanced then there were people who had never coded before.

I: You think that people who've coded a lot before had a lot of advantage?.

P: Definitely because there were things that like… some of the things that (unintelligible) other people, it was just like the back of their hand to them so.

NU Student

The participant below had studied programming and witnessed the advantage first hand.

I: ...To what extent do you feel like your pre college experiences prepared you well for college?

P: I would say really well, especially in comparison to other people I talked to who never programmed before and I definitely have an advantage, in that respect.

NU Student

Participants describe a system that rewards privilege and disadvantages the less privileged, processes that most of the participants seem unaware of. After discussing the limitations of this study, we will situate this data in the meritocratic culture of engineering education in the final section.

V. LIMITATIONS

This work was done during what we hope are the later phases of the COVID-19 pandemic. First-year college students were, and had been for nearly two years, under substantially more stress than usual due to being exposed to online learning, illness and death of family members, and social isolation. The burdens of the pandemic were not shared equally among students, with students from lower socio-economic backgrounds, and systemically marginalized racial/ethnic groups experiencing considerably more stress than others [25]. It seems likely that these highly stressed students were less willing to do optional events like take the ECTD and be interviewed, even with financial incentives. Our population of students cannot be viewed as representative of these institutions in any sense. We responded to this limitation by concealing the number of participants who reported various themes to avoid having readers make unsupported projections. In general, however, the fact that the most stressed students, who are likely to come from less privileged backgrounds, seem less likely to respond to participant recruitment efforts means that the stresses we saw at SWU are likely understated, not exaggerated.

The methodological choice to have a single person code the transcripts prevented questions of inter-rater reliability and assured greater consistency in the application of the codebook. However, this process means that the inevitable blind spots of any single person went unchecked. There may be interesting patterns that exist in the data that this coder did not identify.

The number of MWU students used in the analysis was smaller than desired. This limited our ability to make meaningful comparisons with MWU, and resulted in no MWU students being quoted in this paper.

The introductory engineering classes where participants were recruited had different audiences. The students at NU and MWU were in majors where computing is more obviously essential, e.g. computer science or computer engineering. This probably increased the number of students with prior programming experience at these institutions and may have resulted in under sampling of students without this privilege.

VI. DISCUSSION AND CONCLUSIONS

The comparison of engineering major entry policies between the three institutions shows that NU students were not experiencing grade stress related to getting into their major since they matriculated directly to their major, while examination of policies at MWU and SWU shows that SWU is more competitive and uncertain. The two majors that are restricted by GPA at MWU have a lower and fixed grade threshold as the only criterion, and were not well represented in our participant pool. This is a possible reason we did not hear about grade stress from participants at MWU. High GPA thresholds for admission to a major could be reducing student confidence at SWU. Seymour and Hewitt have documented that students losing confidence in the ability to do science, mathematics and engineering (SME) can lead to loss of interest in SME, and attrition [26].

When faced with stringent GPA requirements for major entry, every advantage matters. Students that have AP experience, especially in mathematics and physics, have a leg up on the competition [24]. The integration of computer programming into the introduction to engineering courses at all three institutions is adding another area where students from privileged backgrounds can gain advantages over others.

Because of its high GPA requirement, this effect is particularly acute at SWU. Recent work by Main et. al. examined experiences in primary, secondary, and tertiary education that often lead students to choose majors in engineering [27]. Many of these experiences are related to educational privilege (e.g., STEM hobbies, college-related outreach experiences, professional role models, extracurricular activities). Lareau has shown how extracurricular activities exclude students from poor and working class backgrounds [28].

Computer programming and/or computational thinking is a particularly troubling addition to the list of educational privileges that benefit engineering students because these classes are less available in secondary education than AP credit calculus and physics. Only half of U.S. secondary schools teach any computer programming [29]. Margolis's critique of US secondary education in computing shows social structures that result in systemic marginalization of students from minoritized racial/ethnic groups in computing [30]. Adding computing early in an engineering curriculum without providing support for those without prior experience is likely to decrease the ability of students from many systemically minoritized groups to succeed in engineering and decrease the already dismal diversity of engineering students.

Students who are willing and able to take calculus, physics, and computing courses, especially courses that grant AP credit, are benefiting from the US educational system's design. US primary and secondary schools are largely funded locally, instead of at the state or federal level, in an ingeniously inequitable system that assures that the children of those that have more resources are likely to get a better education [31]. This system allows students at well-funded schools to have access to educational opportunities that are not available to all, and especially less available to many of those in groups that are systemically marginalized in engineering.

This system has played out in a harsh way for some of the students we interviewed at SWU. The design of the first-year program creates intense grade pressure at the time when students are making the already challenging transition to college-level expectations. Student uncertainty about the criteria for admission to specific engineering majors is leading students to focus exclusively on automatic admission, which is based on a high GPA. Students with high levels of educational and financial privilege are able to excel and sometimes strategically game the system to increase their likelihood of being admitted to their engineering major of choice. The privilege of getting into their engineering major of choice may beget many other privileges for these students. Other students wait and hope that they can get into their desired major though what they perceive as an uncertain back door.

The decision by SWU to use GPA as the central criterion for certain admission to engineering is an example of the myth of US higher education being a meritocracy [32]. The assumption at SWU appears to be that the "best" engineering students—the ones they want to admit without any additional scrutiny—will have high GPAs. But GPAs measure things other than merit and are vulnerable to inflation through the accrual of privileges, as our data has demonstrated. Who is really the better student, in the long run? Is it the one who took two years of calculus in secondary school and got an A (4.0) in calculus in college, or the one who had only algebra in secondary school and got a B (3.0) in Calculus 1? The former student seems to stand a better chance of being in their preferred engineering major at SWU.

Many scholars have discussed the impact of meritocracy in engineering education, and how the meritocracy needs to be recognized and disrupted. Riley showed how terms like rigor have been weaponized in engineering education and engineering education research to perpetuate inequities [33]. In her critique of meritocracy in engineering education, Slater brought forward the unwillingness of engineering programs to provide appropriate preparatory experiences for the "unredeemable" students who come from under-resourced backgrounds [34]. Hoback recognized that even if appropriate preparatory experiences were provided, the additional time needed to complete an engineering degree could leave students without sufficient scholarship support to complete their education [35]. Stevens et. al. showed how engineering students justify their high future salaries based on hard work done in college, a perspective that allows students to ignore inequities [36]. The dire consequences of inadequate academic preparation for engineering students was discussed in Talking About Leaving Revisited [37], where students who described themselves as well prepared had often taken AP calculus and science classes, advantages that are only available to some students in the US. In addition, the existence of classes perceived by SEM students as being weed-out classes is indicative of meritocracy [37].

Computer programming is an important skill for future engineers to learn. The importance of this topic seems likely to grow in the future, including the possibility that ABET might include it within its general criteria for accreditation. The time when this topic is introduced, however, needs careful consideration. Students in majors where computer programming is at the core of the discipline, such as computer engineering or computer science, need to learn programming early to allow expertise in the area to develop over time. For students in majors where programming is not at the core of the discipline, care must be taken to avoid creating unintended inequities.

An institution or program that teaches programming and computational thinking early in the curriculum must be aware of the inequities the curriculum may be exacerbating and try to mitigate the impact of educational privileges. Creating separate sections for students without prior programming experience was pioneered by Cohoon [38]. This strategy is used with success at the University of Oklahoma. Students wishing to take introductory courses fill out an online survey that first gauges their programming background and then requires answers to a few short programming questions. Students are preliminarily placed into classes, and their placement is reviewed by the instructor and negotiated with students. Students without prior programming experience participate in an additional two-hour laboratory each week where they perform pair programming, a practice shown to support marginalized student success [39]. Other strategies for mitigating educational privilege in computing should be developed, implemented, and assessed.

VII. BIBLIOGRAPHY

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