From Their Perspective : What underrepresented students in engineering say about the effect of assessment and reporting practices on their level of confidence.

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Abstract

Existing studies confirm that people of color, women, and rural students are underrepresented in engineering and that those groups who are in engineering report lower levels of self confidence than their peers. However, little research has been done to examine the effect of specific assessment and reporting practices - for example, the publishing of medians - on these students' reported level of confidence. This paper aims to fill that gap by focusing on how underrepresented students describe the effect of different assessment and reporting practices on their level of confidence.

In order to explore how current assessment practices affect underrepresented students from a holistic perspective, both engineering students and faculty were interviewed. Interviews were conducted with 3 engineering professors and 10 engineering students from five different institutions across the United States. The variation in assessment practices included some institutions that published class grade statistics (medians, means etc) and some that did not, and institutions that practiced mastery-based learning and others that did not. The interviews suggested three main ways that assessment practices may reduce confidence and undercut learning of underrepresented engineering students. Here, the terms assessment and reporting practices do not refer to a specific type of assessment practice. Rather, the researchers focused on using qualitative methods to understand how students felt about assessment and the way they receive feedback (eg. tests, letter grades, class statistics, hands-on projects) in broad terms to better inform future research studies.

Engineering schools are increasingly trying to increase diversity and improve retention of students from underrepresented backgrounds. However, if assessment practices have a negative impact on confidence in engineering, and if those assessment practices don’t represent substantive differences in mastery of engineering principles and skills, the cost may be in diminished persistence by otherwise qualified students, especially underrepresented students. Thus, this research can inform assessment decisions in ways that support better outcomes for underrepresented students.

Introduction

In the United States, there is a significant gap between underrepresented groups in engineering and their percentage in the total workforce population [2]. The truth is, engineering has a

"diversity" problem [1], and this problem must be addressed for the U.S. to compete effectively in the global marketplace [2]. The engineering profession, especially, needs better representation to ensure that the solutions it develops are responsive to the diverse needs and interests of the people it serves [1]. In other words, the profession needs diverse talent. To the extent the way we choose to assess weeds out students not based on their capabilities, but based on their experience of the assessment, the profession loses talent it needs to support innovation. The topic of 'diversity' is also increasingly relevant and has become ever more difficult to address given recent rulings to end affirmative action. The importance of diversity in the profession and the current climate around the term 'diversity' further highlight the need to bolster the engineering pipeline to attract, retain and support underrepresented groups. Thus, to the extent that students who struggle in engineering are disproportionately underrepresented students [3]-[4], it is important to examine all aspects of engineering education that could potentially weed these students out, including assessment.

Little research has been done to examine the effect of assessment practices on underrepresented groups in engineering. Oftentimes, underperformance has been thought of as a failure of the student rather than a product of inequities and harmful practices within the methods of assessment and reporting themselves [5]. As this research reveals, students report that assessment and reporting practices greatly impact their confidence levels, and previous research shows that confidence or self efficacy greatly impacts perseverance in the major [6]. If underrepresented students in particular say that assessment and reporting practices negatively impact their confidence and are not always accurate representations of their learning, then these students might be discouraged from persisting in the engineering major, thus further perpetuating the diversity problem that already exists in the profession.

This paper explores how students describe the effect of assessment practices on their perceived sense of efficacy. Specifically, it examines whether students report differences in their sense of self-efficacy in response to different kinds of assessment (eg. tests vs. hands-on projects) and reporting of grades. Examining what underrepresented students in engineering say about their institutions' current assessment and reporting practices can bring us closer to equitable outcomes and assessment for inclusion [5].

Literature Review

Existing research confirms that people of color, women and rural students are underrepresented in engineering and are less likely to persist in the major once in college [7] - [13]. For people of color, ethnic-racial identification is a significant predictor of persistence in engineering, and STEM more broadly: only 43% of Latina/o students and 34% of Black students persist in STEM once in college, compared with 58% of white students who persist to earn a STEM degree [3].

Women, too, have lower persistence rates in STEM (48%) when compared to men (65%) [4]. Rural students also leave engineering at higher rates than their peers - one study found that rural students are 7% less likely to graduate with an engineering degree than students coming from a suburban area [14]. The significant underrepresentation of students from these groups provides a basis for paying attention to what they say about their experiences in engineering education .

The reasons these underrepresented groups leave engineering is related to several factors including their pre-college academic preparation, level of exposure to rigorous math and science courses [15] - [16], and a lack of a sense of belonging and mentors in engineering [17] - [20]. Another major predictor of persistence in engineering is self efficacy [6], which refers to an individual's belief in their capabilities in a certain domain, as well as being able to exercise control over their success in said domain [21]-[22]. This positive relationship between self efficacy and persistence in engineering is especially true for underrepresented students - i.e. students with higher levels of self efficacy are more likely to persist in the major [23] - [24].

Bandura highlights four sources of self efficacy - mastery experiences, vicarious experiences, social persuasion and physiological states [21]-[22]. Mastery experiences affect self efficacy the most and are based on re-collections of prior related accomplishments and hands-on experiences. Vicarious experiences are based on comparison - i.e. students' beliefs in their own skill based on the skills of their peers. Social persuasion or verbal persuasion involves positive and constructive feedback from professors and role models, and physiological states refers to experiencing anxiety and stress about one's capabilities and thus doubting one's ability to succeed.

This study builds on previous research around self efficacy by focusing on the effect that assessment practices have on the reported self-efficacy of underrepresented engineering students. Prior research in this area has not focused on underrepresented students, nor has it examined broader assessment practices beyond grading; for example, the publishing of medians. This research is also unique in that it includes the perspectives of both students and instructors on assessment practices and how they affect students' perceived levels of self efficacy.

Methods

This paper reports findings from interviews collected during Summer 2022. 13 interviews were conducted. The sample consisted of 3 professors and 10 college students who identified as coming from an underrepresented community. All of the students were either engineering majors, students who intend to be engineering majors or students who intended to major in engineering and switched to computer science. Students were in various years and came from 5 different institutions. As we oversampled students underrepresented in engineering, our purposive sample is not representative of engineering students in either race or gender.

Underrepresented students, in particular, were oversampled given that they are more likely to be affected by inequities in assessment and reporting practices.

Interviews were conducted with two goals in mind: to understand how underrepresented students feel about their institutions current assessment and reporting practices, as well as to better understand their experience learning mathematics, a core subject/precursor to engineering. The researchers wanted to more broadly understand what factors dissuade students from pursuing engineering, and so were interested in both students' identity and confidence development as well as their experience learning math. This paper, however, focuses only on highlighting the learnings from what students said about assessment and reporting practices on their level of confidence.

We disaggregate the sample by status (professor or student), gender and race/community based on self identification.The table below shows the breakdown of interviewees. The totals in the table below do not sum the number of interviewees as some interviewees identify as coming from more than one underrepresented community. For example, there was a BIPOC female rural student.

Table 1. Interviewees Disaggregated by Gender and Community based on Self Identification

	Male			Female		
	BIPOC	Rural	White	BIPOC	Rural	White
Students	5	1	1	3	2	1
Professors	2				1	1

We used a purposive sample - students were selected because they either majored in engineering or intend/intended to major in engineering and came from an underrepresented community, and professors were selected because they teach engineering at the college level. Once the potential interviewees were identified, we reached out to them via email to set up an interview by Zoom. The interviews lasted between 30 and 60 minutes and were recorded for transcription purposes. Interviewees were not paid for participation.

The interview protocol was developed specifically for this project. The prompts from the protocol that focused on assessment and identity are included in the appendix of this report. Separate questions were designed for students and educators. Questions were designed to elicit a recounting of the participants' experiences building engineering identity and their experiences being assessed.

To analyze the interviews, a partial grounded theory approach [25]-[26] was used. Two researchers independently read the responses and came together to identify broad themes for a thematic content analysis - some of which were determined prior and others were decided as the data was examined. One researcher then coded the interview responses according to these agreed upon broad categories to create 'buckets' of responses. Two researchers then further read the responses in each 'bucket' to come up with more specific sub-codes. The researchers then independently compared sub-codes, discussed discrepancies, reorganized, and came up with a final set of sub-codes and clear definitions for each. The interviews were then re-coded by one researcher according to the final set of sub-codes and definitions. The process of coding and analyzing was a combined effort of 2 white women with backgrounds in engineering and education, and a black female engineering student.

Findings and Discussion

The interviews revealed that how engineering students are assessed can reduce confidence, lead to comparisons/create a culture of competition, and undercut learning. This happens through three main ways:

1. Ranking or the publishing of class grade statistics (eg. median, highest grade, lowest grade, class average)
2. Grades taking the focus away from learning and distracting from more meaningful evaluation and feedback
3. Using grades as a measure of self worth/confidence

For each section, multiple quotes from students and educators are given. These were purposely included to emphasize how certain assessment and reporting practices make students (and educators) feel. With qualitative research, it is necessary to allow for multiple or lengthy quotations to bring the main points across.

1. Ranking or the publishing of class grade statistics (eg. median, highest grade, lowest grade, class average)

When asked about how they feel about the way their institution reports grades, every engineering student who attended a school that reported class statistics said that they have either been negatively impacted themselves or have seen others be negatively impacted by the reporting of such statistics. More specifically, when students are made aware of the median grade for a class, it makes them compare themselves to other students, which can erode their confidence.

For example, one student stated:

> *"And so the class median could be an A, but if you get an A- , it makes you think "I'm below average" ...it's like the school is actually saying, "hey you should hate yourself" ... Even going into Canvas and seeing where you are in comparison to the median, it sucks. And I know you're not supposed to compare yourself to others, but it's easy to do here at _____ . " [student]*

Students reported that when they saw class statistics, it made them feel inadequate, and they were even concerned about the repercussions it could have on their employability. For example, another student said:

> *"I don't like how on the transcript they show the median. You might be getting a B+ or an A- and you're below median. I feel like that's a little sad, and I don't want my employers to see that because it's still an A- at an Ivy League." [student]*

Thus, the publishing of class statistics not only affected students' views of themselves, but also had them concerned about how others would view them once seeing these statistics. The feelings of inadequacy are especially harmful to underrepresented groups. Firstly, many underrepresented students already feel like they do not belong in engineering, a white male dominated field. By reporting assessment results in a way that promotes comparison, this further perpetuates these feelings of not belonging and may dissuade them from continuing in the major. Additionally, many underrepresented students attend college to get a well paying job and break cycles of generational poverty. Thus, if underrepresented students feel like certain reporting practices make them look unfavorable to employers, especially in comparison to their white male peers, this too provides further reason for them to leave the major.

On the contrary, it is interesting to note that students who attended a school where class statistics were not reported did not mention comparing their performance to other students. In fact, these students actually expressed that they did not want class statistics reported as this leads to comparison with peers, but preferred having a system that rewarded good performance.

For example, one student stated:

> *"I think that is good [that they don't report medians]. There are many honor societies for your major or department. I like the way it is reported here. I prefer to have a reporting system that doesn't measure you against your peers, but rewards you in the form of an honor society, certificates, luncheons and Dean List's." [student]*

Students also said that such rankings and comparisons do not provide helpful feedback as to how the student himself can make improvements, but rather takes an emotional toll:

> *"It depends on how you're performing on the scale. If your performance is behind the scale, you're going to feel that you're inadequate or you're not good enough. But if you're performing above the scale that tells you that you are doing pretty good. But I don't think it's that important or essential. Maybe it's good for the school to keep track but not essential to you. You're not going to change your learning style or approach based on how someone else is doing. Their performance does not directly relate to how you're doing. But, it could have an emotional effect. It can take your focus away from yourself and proving your abilities." [student]*

Like the students, educators also realized the danger of such comparisons and how unfair they are given that students are coming from different backgrounds and different levels of preparation. As one noted:

> *"And students who don't realize that they come from different levels of preparation, compare themselves with students who have benefited from a rich high school experience in tutoring." [Educator]*

Not only do these comparisons negatively affect students individually, but they can affect the culture of the entire school. As one professor noted, such comparisons create a culture of competition, saying:

> *"The downside of this is that it can create a competitive nature that says it's not enough to have learned. I don't think that's the healthiest exercise and it might be an over correction. I think that [the publishing of medians] came out of concerns that we can't have everyone graduating with 3.85 averages. In the end, you want people to have mastered a certain body of work but this may not be the most helpful way to reach that goal." [Educator]*

Professors also said that the current grading system forces them to produce a linear ranking of their students, with students who have higher grades at the top of the ranking, and students with lower grades at the bottom. Such a linear ranking does not necessarily capture the individual progress that students have made, but might be the result of some students having prior experience with the subject material. A more equitable system, then, should capture and report a student's individual progress and mastery of the material, not merely place a student's performance in direct comparison with the performance of their peers. Professors also reported frustrations with having enforced medians and being forced to produce this linear ranking.

For example, one professor stated:

> *"If every student masters everything perfectly, then everybody should get an A. That's not what our education system allows us to do. We get in trouble if we do that." [Educator]*

In other words, these professors expressed that grades are assigned to satisfy the requirements of the system, which, as was mentioned before, does not account for students' varying backgrounds, and thus perpetuates inequities. As one professor noted:

> *"So it's complicated because what we're supposed to produce is a linear ranking of our students. And that makes no sense. Again students come in with different knowledge into the classroom and so automatically those who have more prior knowledge do better." [Educator]*

Once again, underrepresented students will disproportionately feel the negative effects of assessment practices that lead to the production of linear rankings because they are less likely to have robust academic preparation prior to pursuing the engineering major. There is no context given behind these rankings, so it is easy for underrepresented students in particular to feel inadequate in comparison to their peers, rather than focusing on their individual growth and realizing that their peers may have had prior experience and access to resources that they did not have.

2. Grades taking the focus away from learning and distracting from more meaningful evaluation and feedback

Not only do certain assessment practices encourage students to make unfair comparisons with other students, but how students are evaluated can further undercut learning when students sacrifice learning to ensure that they get a desired grade. Students sometimes prioritize submitting the correct answer over actually understanding the material. Additionally, when students have the option to have a grade excluded from their transcript/excluded from the calculation of their GPA, it affects whether or not students place an emphasis on learning in the course. Assessment practices that capture a singular result and not the student's progress often lead to students prioritizing a grade over learning.

One student explained how she focused on a grade rather than learning in many of her courses:

> *"Especially with the NRO* and Math 3, Math 8, Math 13. I realized I had heavily relied on online resources to give me the answer. I was looking up the answers, not how to do it, just because I didn't want to get a 66 on a WebWork**, because that would mess up my grade." [student]*

* Non Recording Option (NRO): An option whereby students may elect, under certain conditions, to exclude a grade from showing on the transcript or to be calculated in their grade point average in one regularly graded course a term.
** WeBWorK is an online homework delivery system primarily used for mathematics and science.

Another student similarly expressed that the way she was being assessed (open note tests, dropping her worst grades) affected the effort that she put into the class and her overall learning:

> *"It's more so that I entered college during COVID. I feel like that really affected the dynamics of the classroom, especially since everything was online. I always wonder, if I had started college during a normal year, if perhaps I would be a lot better at math and physics because a lot of the tests were open notes, or things like that, or you could drop all your worst grades. We were just scraping by. Whereas if I was in an actual, legitimate math and science class, I perhaps would've tried a little harder and learned more." [student]*

As a result, the first student mentioned above focused on high grades in her Web Work assignments, not on actually learning the material. The assessment system captured whether or not she inputted the correct answer, not whether or not she actually understood the material. The other student described not trying as hard or learning as much in classes because of open note tests and being able to drop her worst grade(s). In both instances, students were most concerned with the appearance of their transcripts. Students were prioritizing a grade over learning, and grades were not capturing what they were supposed to. Students do admit, though, that getting a good grade does not imply mastery of the material.

For example, one student said:

> *"Yet, getting good grades doesn't always mean you understand the concept. Sometimes you run into a challenge in the real world and then realize that you don't really understand it." [student]*

Indeed, grades do not tell the full story. As seen above, a student may get a passing grade in a course, without understanding the material. This situation is especially harmful for underrepresented students. Underrepresented students, in particular, are concerned about their employability as revealed in one of the quotes above and the quote below, and thus might feel the need to do whatever it takes to get a desired result as current assessment practices only capture an end result. This works to diminish their confidence, as they are aware that they don't actually know or understand the material. Not grasping the material can have a cascading effect when

advancing to higher courses, as students will again lack confidence from not having a good grasp of the foundational material. The converse of this situation is also true: a student may put in a great deal of effort to really understand the material and still not receive a passing grade. This situation is also potentially harmful to underrepresented students. If a student is putting in a great deal of effort, but is still receiving a low grade, this may dissuade him from continuing in engineering. In these instances, qualitative feedback or comments can therefore provide crucial information about the student that is not captured in letter grades.

For example, one student said this about qualitative feedback/providing further context beyond the grade:

> *"One thing that I do like is that there is a citation* section that's included in the unofficial transcripts. I like this particular section, because if you submit this to a job, someone who's recruiting, someone's reviewing your transcript, it shows a side of you that is not represented in the letter grade you get. I know that there was one professor who gave a student who had a failing grade a citation for consistently trying to learn in the class and not giving up. The citation tells a different story." [student]*

*Citation - Statement (indicated by an asterisk after a letter grade) entered by faculty members to provide an official record of information about undergraduates who have made particularly favorable impressions on members of the faculty because of their unusual talents, dependability, initiative, resourcefulness, or other meritorious characteristics that are not indicated adequately by academic grades.

Opportunities to comment on a student's qualities or progress thus helps to provide context beyond a letter grade. However, this kind of feedback, though extremely useful, is not required and thus is often not included.

Further, all professors interviewed said that grading is a part of the job that they do not particularly enjoy. Professors expressed that qualitative feedback matters more than the grade, however, grades often distract from this more meaningful part of evaluation. Professors shared that the focus of assessment should be to engage with and provide feedback on a student's progress, not to assign a number or letter grade.

One professor explained:

> *"I enjoy reading and commenting on papers. The actual grading is not a part of the job that I relish, it's just a part of the process. The more meaningful parts of the evaluation are engaging with the students' work and providing feedback. One of the favorite classes I taught was at ___ when I never put a grade on anybody's paper. I just gave comments and nobody was waiting for a grade." [Educator]*

Being able to comment on a student's progress and capture their individual learning journey is especially important for underrepresented students who are coming from varying backgrounds of prior academic preparation. A letter or number grade, however, simply does not allow for this kind of context, thereby working against the students who probably need this kind of meaningful feedback the most.

3. Using grades as a measure of self worth/confidence

When students were asked to recall a moment where they felt confident in a Math or Engineering class, 70% attributed their confidence to receiving a high grade. Some replies were :

> *"Math 1, because I got an A in the class and for the midterm, this was like the first exam where I didn't feel nervous." [student]*

> *"Definitely Linear Algebra. When I got my first exam back for that particular class, it was the highest score that I've gotten at _____, which was really nice to see." [student]*

These responses show that many students in the sample used grades as a measure of success. It is what made them feel proud, accomplished and confident. Educators realize the harm in such a "grade - focused" perspective. Note what one professor said:

> *"Rather than feeling good about themselves because they've learned something, accomplished something, they will feel good about a grade. Life will not grade you once you leave ____ and so it's unhealthy from a variety of perspectives." [Educator]*

Students thus made it clear that what makes them feel confident or proud is getting a good grade. However, when students were asked what makes them feel like an engineer, 10/10 students said that doing projects is what makes them identify as an engineer. When students were asked to recall a moment where they felt like an engineer or to explain what makes them feel like an engineer, some replies were:

> *"Seeing the finalized project that works in front of my eyes, I feel that's what makes me feel like an engineer." [student]*

> *"After my ENGS 37 project, yes. I'm definitely an engineer." [student]*

It was not only students who identified projects as boosting their confidence in their engineering ability. When engineering professors were asked what students are doing when they seem to be the most confident, all of them responded that students seem to be the most confident when working on projects that challenge them.

They explained:

> *"I think they [students] do best when they're working on a project or a piece, a bit above what they think they can do." [Educator]*

There thus seems to be a disconnect between what gives students confidence and what actually prepares them for the engineering profession. Most students said grades, specifically from tests and exams, make them feel confident. However, what made them feel like an engineer was doing projects. The disconnect here highlights that grades from exams/tests are a mechanism students use to feel good about themselves, but that these forms of assessment are not what students say makes them feel like they are actually developing engineering skills. Thus, an underrepresented student may feel dissuaded from the major on the basis of a bad exam or test grade, having not had sufficient opportunities to develop their engineering identity through projects. The question then arises whether the purpose of exams and tests is to simply ask questions for students to answer, or is it to test their mastery of and develop confidence in their ability to use the skills taught in the course to solve real world problems?

Limitations

There are many limitations of this exploratory study. Firstly, the sample size was small and is not representative of undergraduate engineering students across the country. Additionally, the interview protocol focused both on mathematics and assessment. However, to further explore how assessment and reporting practices affect underrepresented students, a more in-depth protocol with solely assessment questions could be used. Additionally, while this study relates what students have said about their institutions' current assessment practices, further work can be done to examine some of the possible solutions to concerns that students have highlighted. Some solutions implied in students' responses are to avoid publishing class statistics, provide qualitative feedback in assessments that captures a student's individual progress, offer more opportunities for project work and design tests and exams to actually assess mastery of the relevant engineering skills.

Conclusion

In conclusion, underrepresented students say that assessment and reporting practices can and do have an effect on their confidence levels in engineering. Unfortunately, assessment practices tend to capture a result absent of the student's individual progress and some reporting practices (for example, the publishing of class statistics) encourage competition and comparison, which diminishes students' confidence levels. Other assessment practices (for example, tests) are

mechanisms that students use to feel good about themselves, and often lead students to prioritizing the result of these assessments over learning the material. This paper highlighted some of the ways in which these practices thus further perpetuated inequities. Additionally, all students stated that assessment in the form of projects is what made them feel confident in their engineering ability. Therefore, assessment and reporting practices can affect students' confidence or perceived efficacy in the engineering major, which can ultimately affect whether or not they persist in the discipline. Thus, if institutions want to attract and retain diverse students in engineering, they should examine their assessment and reporting practices to ensure that they do not further exclude underrepresented students.

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Appendix - Interview Protocol

Interview length : 30 - 60 mins.

FOR STUDENTS

Warm-up Questions:

1. What institution do you go to?
2. What year are you?
3. What is your major?

Assessment

1. What is the grading system like at your current institution?
2. How do you feel about your institution's current assessment system?
3. When you receive a grade, how do you respond? Why do you respond that way?
4. Has the way you've been assessed ever affected your learning?
5. Have you ever taken a class where you particularly liked how you were assessed?
6. How do you feel about the way that your institution reports grades?

Engineering Identity and Confidence

1. Can you recall a moment where you felt confident and/or proud of yourself in a math or engineering class? Describe it.
2. Can you describe any moments that cause you to think "I am an engineering major!"?
3. When was the moment when you began to think of yourself as an engineer? What was happening that made you think this way? What were you doing or what happened at that time that made you feel that way?

FOR PROFESSORS

Warm-up Questions:

1. What is your position/title?
2. Where do you teach?
3. What do you teach?

Assessment

1. How do you currently assess students?
2. How often do you evaluate your assessment methods?
3. What do you think the effect of your assessment strategy is on students and students' attitudes?
4. From your experience, are there any assessment strategies that you think have worked best for your students?
5. When you give grades, what are the kind of reactions that you get from students?
6. How do you feel when you grade students?

Engineering Identity and Confidence

1. In your opinion, what is that students are doing when they seem to be the most confident?
2. Have you noticed anything about students who (in your opinion) seem to be confident in their engineering ability?