How do Engineering Educators take Student Difference into Account?

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Abstract - **This paper addresses the extent to which, and the ways in which, engineering educators take student differences into account when making teaching-related decisions. We have found that educators deal with multiple types of student differences, although rarely in the way research recommends (e.g., focusing on learning styles). More often, educators differentiate students in terms of class standing, level of interest in a subject matter, and behavior. Our findings, illustrated by three case studies, demonstrate a variety of ways in which educators differentiate students. Generally, data such as this works against the perception that engineering educators at research universities are not taking into account educationally relevant student differences. However, to improve engineering education we should recognize and learn from the ways in which educators differentiate their students.**

Index Terms – Student difference, Diversity, Decision-making

INTRODUCTION

It is considered good practice to teach with an awareness that groups of students will not be homogenous, and *will* differ. "The more thoroughly instructors understand the [student] differences, the better chance they have of meeting the diverse learning needs of all of their students" [1, p. 57]. Research tells educators to take into account specific student differences, including learning styles, socio-economic status, race, and culture. We are particularly interested in educationally relevant differences that would impact student learning. In theory, each type of educationally-relevant difference implies a specific teaching practice. For instance, as a benchmark for considering student difference, Felder and Brent focus on three types of differences: learning styles, approaches to learning and orientations to studying, and intellectual development [1]. Felder and Brent describe how these student differences translate into concrete teaching practices and they offer strategies for aligning such teaching practices to meet the three types of differences. In one example, they encourage educators to consider using different types of learning tasks (e.g., varied problems) to practice inclusive teaching.

In dealing with students, educators are advised to take student differences into account, particularly with reference to traditional diversity initiatives (racial, ethic, gender). The decrease in diversity of student groups is of particular concern, especially when considering the negative consequences [2]. NACME continues to reveal the stagnating, and even decreasing numbers of minorities in engineering departments [3]. In addition, considering racial, gender, and ethnic differences is critical in attaining student diversity [4]. This important issue has been debated and discussed; however, little has been written about how engineering educators examine, consider, and use student differences in their teaching practice.

As a result of research in these areas, a great deal is known about how students differ from each other, how differences can affect student learning, and how differences could be taken into account in teaching practice [1, 4-8]. However, little is known about how educators think about, and take student differences into account. This paper addresses this gap by focusing on the following questions:

1. To what extent do engineering educators take student differences into account in their teaching?
2. What types of differences do educators take into account?
3. How do these types of differences map to the types of differences educators are told to take into account?

Our approach is motivated by the belief that answering these questions is an important part of helping engineering educators take student differences into account more effectively. Different approaches might be required to help educators who are already taking difference into account and those who aren't (i.e., linked to question 1 above). Further, such tailored approaches would be helped by information on the types of student differences educators already take into account and how these differences align or do not align with the types of differences (e.g., learning styles) that the literature advises educators to address.

In the next section, Background, we summarize research on teaching that serves to further motivate our questions, as well as provide initial expectations for their answers. In the Methods section, we discuss how we collected data through the Critical Decision Method interviews and how we analyzed the transcripts of these interviews to isolate areas where the educators alluded to issues of student difference. In the Results section, we use a combination of quantitative and qualitative results in an effort to answer our research questions. Finally, in the Discussion section, in addition to summarizing the results, we address the issues of generalizability and implication.

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BACKGROUND

Our work starts by assuming that teaching is a complex activity, and as such, it is possible that educators may not be taking student differences into account. It further assumes that if educators are taking student difference into account, their approaches may or may not map easily to the types of differences they are advised to consider. These two assumptions guide the framing of the questions that are addressed in this paper.

Why do we need to ask whether educators are taking difference into account at all? We can offer two reasons: first, it is likely that there are both educators who do and educators who don't take difference into account and, second, the variation in the ways in which educators address student differences would be important to understand in order to decide how to proceed with helping an educator take difference into account. By focusing on the types of student differences that these educators do consider, we can align these practices with potential teaching strategies (i.e., implications).

Research on teaching suggests that some educators may not be accounting for student difference. For example, Kember characterized *overall* teaching conceptions as ranging from teacher-centered to learner-centered [9]. While a learner-centered educator is quite likely to focus on student differences as part of an array of techniques for focusing on learners, a teacher-centered educator—one who generally does not focus on learners—would be less likely to focus on student differences.

Other factors suggest that educators might not have resources to take difference into account. A great deal of engineering training takes place at research intensive institutions where teaching is a small part of educators' positions, which suggests that they may have little capacity for acknowledging or even dealing with student differences [10]. Since teaching is not educators' primary role in these institutions, they often identify with many other aspects of their position, such as being a member of a discipline. In these cases teaching competes with other career demands [10]. Because engineering educators are minimally trained in actual teaching, we can expect a lack of common language. In general, discussions about diversity and student differences can be complex and emotionally charged. Because of these reasons, we started with a general definition of difference and then moved to specific categories, based on the literature [3-8] that motivated our coding categories. In the following Methods section, we will describe this coding process and the overall research methods.

METHODS

In this study, interview transcripts with engineering educators in which they reported on prior teaching decisions were coded for evidence of having taken student differences into account. The coding results were analyzed to address our questions about the extent to which educators accounted for student differences and the types.

Data collection: The data for this study was collected as part of a larger endeavor to understand how engineering educators make teaching decisions generally. The interviews were conducted based on the Critical Decision Method (CDM) [11] where participants were asked to identify critical incidents [12] in the decision-making process. Using the CDM, participants were invited (1) to explain decisions in general and to identify two specific, recent, memorable decisions: (2) a planning decision (defined as a decision made in advance of interacting with students) and (3) an interactive decision (defined as a decision made in the moment). Even though participants were asked about three decisions, many times they talked about many multiple and nested decisions. The participants in the study were 31 engineering educators at a large public institution in the Northwest. The interviews opened with an introductory period in which the educators were asked to talk about their teaching responsibilities in general, and also to react to the notion of "teaching decisions" as a way to talk about teaching. Our analysis (described below) focused only on the decision part of the interview. Focusing on teaching decisions allows us to blend an emphasis on teacher action with an emphasis on teaching conceptions. Because they focus on decisions, our results provide insight into how differences are actually taken into account rather than into participants' ideas about how they believe they should take difference into account.

Data analysis: The analysis was conducted in three phases: segmenting the transcripts, coding the educator segments based on whether or not the educators mention having dealt with student differences and also the type of student differences taken into account, and finally analyzing the results (see Table 1 for example coding segment). For a systematic process, the transcripts were segmented at the turn-taking event (each unique time the participant spoke was coded). The coding process consisted of examining each turn-taking event to determine if it represented a place where the educator was taking student differences into account. The use of idiosyncratic language is important in capturing the true nature of their narratives. Furthermore, a general qualitative principle is to use the participants' language before introducing unfamiliar terms [13]. Because we were interested in staying close to the participants' language, the coding scheme was developed inductively through early interactions with the data. The coding scheme below was the product of this inductive phase. The coding process involved analyzing each turn-taking event and applying all of the codes that pertained. As a result, a single turn-taking event could be coded with multiple codes. For overall aggregation purposes in the analysis, a turn-taking event was considered to be related to the general phenomena of "taking differences into account" if one or more of the codes below had been applied to the turn-taking event. Difference was recognition of students according to:

1. Level: grade level, knowledge, learning style, skill set

2. Behavior: action, conduct
3. Race/Culture: race, culture, social group
4. Gender: female, male, he/she, gender neutral
5. Profession: relating to engineering
6. Socioeconomic status (SES)/Privilege: low income, middle class
7. Subgroups: other than those mentioned above

Furthermore, difference was evident in an analysis of educators' language according to:

8. Quantity: denotation of a subset based on numbers
9. Word Choice: denotation of a subset based on a word ("a few," "some," "most")
10. Other: denotation of a subset other than those above

Table 1 illustrates three participant turn-taking events and how the participant turn-taking events (TTE) were coded for relevance to student difference.

TABLE 1. CODING EXAMPLE

Speaker	Excerpt	Code
Participant	You know, I just remember that a certain kind of problem gave people a lot of difficulty or, you know, I guess sometimes on a more abstract level I'll realize that a certain kind of reasoning is generally beyond many of them, but not all of them, or something like that.	Level; Word choice
Interviewer	Okay. And how do you assess that?	N/A
Participant	Well, I work on grading the exams.	None
Interview	Okay, okay. So it's that type of feedback, whether they're able to sort of answer the test problems?	N/A
Participant	Right. And I think of it in a somewhat statistical sense. So, you know, if, you know, one out of four students gets a particular problem right, I would say that's a hard problem.	Level; Word Choice
Interviewer	Okay	N/A
Participant	And if one out of four students -- if three out of four get it right, typically, you know, I'd say it's an easy problem.	Level; Word Choice

To improve the quality of the results, all transcripts were coded by two coders. In this process, reliability had several purposes. It was used as an indicator of rigor (calculating inter-rater reliability using both percentage agreement—above 85%—and Cohen's kappa as a way to monitor rigor). It was also used as a training tool (by monitoring the level of agreements between the two coders, problems could be detected early) and a way of refining the coding scheme (disagreements were used as a basis for refining the coding scheme).

RESULTS

We use a combination of quantitative and qualitative results to provide answers to our research questions. The quantitative results relate to our initial research questions regarding extent and type of difference through measures of prevalence and coverage. The qualitative results are presented as case studies further illustrating these findings.

We used the results of the coding process to determine both quantitative and qualitative answers to our research questions. From a quantitative perspective, we were able to identify two metrics for characterizing the extent to which the educators took difference into account: the percentage of the turn-taking events that were coded as addressing student difference in some way (prevalence) and the different types of student difference an educator mentioned (coverage). To illustrate what these results looked like in the context of our data and to address our second question, we present three cases from the larger set of data. In order to preserve and protect the confidentiality of our participants, participant names were replaced with random pseudonyms. Other identifying information was removed.

I. Quantitative Results

Figure 1 illustrates some quantitative results, a general view of the data. Every participant took difference into account. Participants covered difference along 2 to 10 of the categories (shown on the x-axis, coverage), but no one talked about difference in terms of all 10 categories. Difference was a small concern—ranging from 3% to 25% of all turn-taking events—in the context of the overall interview (shown on the y-axis, prevalence).

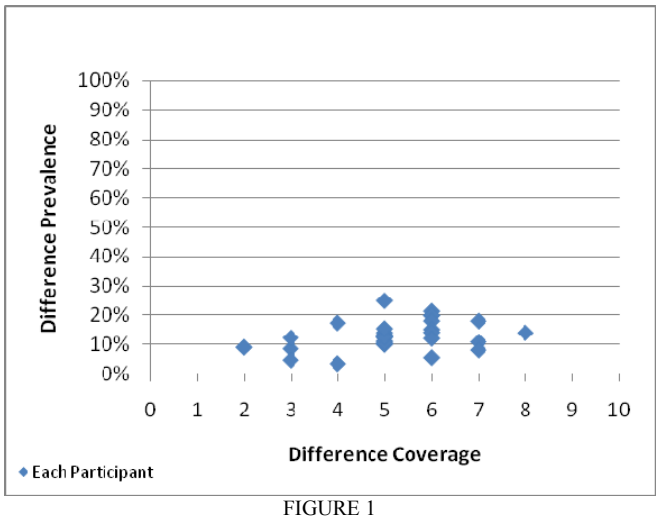

FIGURE 1
THE NUMBER OF DIFFERENCES CATEGORIES (DIFFERENCE COVERAGE) MENTIONED BY EACH PARTICIPANT, AS WELL AS THE PERCENTAGE OF TOTAL TTE'S THAT EACH PARTICIPANT DEVOTED TO DIFFERENCE (DIFFERENCE PREVALENCE).

II. Qualitative Results

All three participants in the cases below represent a range of student difference being considered. Each participant illustrates an important aspect of taking student different into account. Case one illustrates a participant who focuses on student difference in many categories, particularly student behavior and level. In case two the participant focuses on student difference in many categories, but with an emphasis on level. The participant in case three minimally focuses on difference. These cases are a means to examine the patterns and themes among a subset of participants, further allowing a deeper examination of participants.

Case Study 1 (Nathan): Much student difference in many categories with a focus on behavior and level

When talking about decisions in general, Nathan focuses on issues surrounding plagiarism and involving plagiarizers. This discussion is highly interwoven throughout all aspects and decisions of the interview. Nathan describes this situation as "one that does come up quite often that's kind of a bummer is the misconduct issue, because I'm pretty strict on that, because I assign term papers, I have to deal with plagiarism."

In the context of plagiarism, the type of students who plagiarize and the number of students who plagiarize are differentiated from other students (i.e., non-plagiarizers). In this context students are differentiated primarily based on behavior—making excuses: "I didn't start it until 12 o'clock the night before it was due, and at 1 o'clock I was tired and I just grabbed something off the internet and turned it in." Furthermore, these students, plagiarizers, are classified as different types: ESL students, excuse makers, and even further as "trying to get through the system any way they can." Because of this mindset, behavior—getting through the system any way possible—has become more pronounced. Even though a "minority" of students (i.e., "small number" and "five to two students") cheats, it is a priority to catch them.

Nathan's planning stage decision involves the fact that his graduate level evaluations were much lower than the undergraduate course. Because of this situation, students' individual interests and needs—level—motivated the direction of the course content. According to Nathan, before student input (i.e., student evaluations), the course didn't tell a complete story, so one aspect became the class focus. Therefore, all students worked on different aspects of the same project—telling a complete story.

Another one of his planning stage decisions was the choice to have liberal office hours—"an open-door policy." In discussing this decision, he did not differentiate the students at all, rather clustered into one group, "as never showing up during my office hours." Rather, students show up whenever because of this policy.

An interactive decision involves Nathan trying to work with a non-responsive colleague (e.g., another educator), so students do not have multiple exams on one day. When talking about this decision, Nathan describes the students as a junior year cohort (level) with fixed curriculum. This quantification of "junior year" distinguishes this year from other years (e.g., freshmen, sophomore, senior). Finally, this decision can be considered inclusive teaching (by researchers), in that the curriculum was adjusted to meet their various needs.

Finally, Nathan recognizes both undergraduate and graduate classes are heterogeneous because of the mix of backgrounds, grad classes more so because students come from different backgrounds.

Case Study 2 (Bea): Much student difference in many categories but with a focus on level

When talking about decisions in general, Bea primarily discusses decisions related to engaging students. In striving to engage students, Bea practices inclusive teaching through gauging "where those particular students are." This practice is one of her primary goals. Through inclusive decision-making, Bea discusses students in gender-neutral terms. There is no assumption about gender, unless it is known. When the gender is known, Bea frequently differentiates students based on gender.

Bea's overarching planning decision involved an instance when she was a guest lecturer; however, there were many nested decisions about engaging students from diverse backgrounds. Again, in this situation, the focus of Bea's decision was gauging students' background knowledge level—as related to the content—and in doing so, deciding to add content based on student knowledge. In course planning, Bea believes student "variety" is an integral consideration; students' interest and backgrounds (levels) are important and recognized as different. Bea classifies students as coming in with "similar holes" based on their "knowledge level" (i.e., community college, university). In this instance there is some segmentation of student groups; however, students are not considered individuals. Rather, they are grouped based on certain criteria. Finally, Bea groups students into tiers of "knowledge levels" based on where they are in the degree program. This consideration of student difference impacts how Bea deals with students:

> "Yeah, their knowledge level and where they are in their degree program. So if I'm teaching an undergraduate course for students that are just coming into the program, they're at a different level. They need, in my view, they need some stepping stones. They need some core fundamental material that they can then utilize later on in a more open-ended design case."

An interactive decision involved Bea gauging whether or not students understand the content at a particular level. This mindset takes into consideration that some students will get it and some will not (clearly a consideration of student difference). Several times, one student was singled out (e.g., "a student…"). Through these word choices, particular students are differentiated from the whole class.

Finally, Bea mentions her service work in which she is striving to "encourage more participation from a diverse group of students."

In the context of these types of decisions, Bea is actively engaging in the discussion and consideration of student difference along many dimensions as advocated by researchers. However, in these types of decisions about engaging students and gauging background knowledge, differentiating students based on level was most evident.

Case Study 3 (Eugene): Little student difference

According to Eugene, decision-making is a process an educator goes through to achieve the teaching goals. Eugene's goals are to equip students with knowledge and prepare them to apply this knowledge in the real world.

However, in the context of this decision-making, Eugene does not recognize student difference. More importantly, there is little acknowledgement about student difference in general in the interview. Most of the associated decisions relate back to teaching computational problems, which may or may not contain a discussion about student difference.

In discussing a planning decision, Eugene's emphasis is on "numerical computer simulations" over "the analytical approach." And when he does make such decisions, he considers students' levels (e.g., graduate vs. undergrad). For example, in the undergraduate course the emphasis is more applicable to industry practice and standards to prepare them for the real world. There is recognition of a group of students, "some," who talk to him about graduate school. Students' diverse interests driving the direction of the class—"majority agree…minorities understand." However, the differentiation among students is minimal.

These three case studies highlight the breadth of student difference acknowledged within these decisions. Now, how can these practices potentially be aligned with research models?

DISCUSSION

In this paper, we have presented quantitative evidence suggesting that the engineering educators in our study *did* take student difference into account in the context of the teaching decisions that they reported (i.e., our prevalence results). The educators were also found to consider multiple types of student difference (i.e., our coverage results), although the extent and range of types varied across the participants. Further, returning to the initial questions the qualitative case studies illustrate what these findings about "extent of difference" and "types of difference" looked like for three participants. Two participants were selected because they had similar levels of taking student difference into account (i.e., similar in terms of "extent") yet they took different "types" of student differences into account (i.e., Nathan illustrated differentiating students on behavior while Bea illustrated differentiating students on level). The third participant was profiled as an example of a decision-making account that involved little allusion to taking student difference into account.

A strength of these results is that they were acquired through a data collection process that asked educators to talk about decisions that they had made as opposed to asking them directly about difference. This latter practice could have led to the educators talking about student differences that they think they are supposed to address, rather than focusing on student differences that they do address. A limitation of this approach is that the results could underestimate the extent to which the educators take difference into account—they may have been able to provide additional information if asked directly about student difference.

What we do find interesting about these results are the implications for helping educators more effectively take educationally relevant student differences into account. First, we find the prevalence in these results quite interesting. In the Background section, we had introduced prior teacher research suggesting the possibility that we would find educators not taking student different into account (i.e., the notion of teacher-centered conceptions of teaching [9] and the role of teaching in a faculty career). As a result, it is encouraging to know that educators are taking student differences into account when not doing so might be easier. Further, such a result suggests that efforts to help engineering educators take educationally relevant student differences into account should recognize that educators are quite likely to already be differentiating students. Assuming that Eugene deals with little student difference, we could anticipate thinking differently about helping Bea and Eugene.

Second, our coverage results suggest a spectrum along which educators differentiate students. In addition, the coverage results suggest that many educators are differentiating their students in multiple ways, which further complicates the picture. We believe this may be important because if educators are already taking a variety of student differences into account (e.g., Bea and Nathan), it may be challenging for them to take still other differences into account. For example, since Bea and Nathan are taking a range of student differences into account, it may be cognitively taxing to take still other differences into account. On a more complicated level, it could be that some of the differences that educators are currently taking into account are difficult to align with other types of differences. Or maybe it would be easier because they are already familiar with taking student difference into account. Or it may be more complicated to introduce the concept to an educator who differentiates little among students (e.g., Eugene). Little is known about this issue, but to start we should simply recognize the ways they are differentiating students and support them in their current ways.

Finally, we find it interesting that our analysis revealed little evidence of educators differentiating students based on the types of "educationally relevant differences" that seem to populate the research literature. For example, an inspection of our results from the perspective of Felder and Brent's categories—learning styles, approaches to learning and orientations to studying, and intellectual development—revealed little evidence that any of these differentiations was present in our data. In general, this suggests that the educators' practices are potentially aligned with the general notion of taking difference into account because they *do* take student difference into consideration, but the educators' practices are *not quite aligned* because the type of difference educators are considering are different than the differences discussed in the research literature.

Given the nature of our study, it is reasonable to address the issue of generalizability. For example, do we think that the results at the educator level (they reported on two decisions) generalize to all of the decisions that these educators make? Or that these results across the set of 31 educators generalize to all of the educators at the institution

where the study was done, or even engineering educators in general? While we are less comfortable with generalizing about the educators based on their two reported decisions (e.g., assuming that how Nathan talked about student differences in the context of his decisions is indicative of how Nathan is an educator overall), we are more confident about the generalizability of the overall results to groups of educators. This is based on our sampling approach—our findings came from a sample of 31 educators (around 15% of the educators at the university in which the study was conducted), the educators represented all academic ranks, and talked about two (or more) decisions each. The results may also be transferable to other research extensive institutions, but may not be transferable to other types of institutions. For such situations, our results provide a starting point that could be confirmed with additional research.

CONCLUSION

This paper has addressed the extent to which, and the ways in which, engineering educators take student differences into account when making teaching-related decisions. The results suggest that engineering educators are taking student differences into account, but that the differences to which educators attend may not be aligned with the differences that research suggests educators address. The results suggest the following implications for faculty developers or others interested in helping educators more effectively take student differences into account:

1. Assume that educators are already taking some types of student difference into account.
2. Recognize that changing teaching practice to take new types of student difference into account may vary across educators. Some approaches are (a) adding these new types of difference to existing practice, (b) integrating the new types of different into existing practice, and (c) working to reconcile prior practices with new proposed practices.
3. Coupled with these lenses, consider using a strategy such as a CDM interview to understand the educators' existing approaches to addressing difference so that the new approach that will be required is anticipated and supported.

ACKNOWLEDGMENT

This material is based on work supported by the National Science Foundation under Grant No. ESI-0227558, which funds the Center for the Advancement of Engineering Education (CAEE). A special thanks to Priya Guruprakash Rao for her dedicated coding work; and Jake Ashcraft for his additional insights.

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