

AC 2007-1966: DIVERSITY IN ENGINEERING EDUCATION RESEARCH: INSIGHTS FROM THREE STUDY DESIGNS

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Diversity in Engineering Education Research: Insights from Three Study Designs

Abstract

Diversity is a significant concern in engineering education, as evidenced by the numerous recent calls to recruit and retain more women and underrepresented minorities into engineering majors and professions. Discussions about the importance of meeting the needs of diverse students are widespread; however, there has been less discussion of how to define diversity, and how to actually go about studying diversity in meaningful ways. Given the lack of explicit guidance in this area, new engineering educators may benefit from examples of how their peers are thinking about diversity in designing educational research studies. In this paper we provide three examples of studies of diversity issues in engineering education in order to demonstrate some ways in which diversity can be conceptualized and integrated in educational research. For each study, we discuss how diversity is defined, how the research question addresses the relevant aspects of diversity, how the research methodologies facilitate in-depth understanding of the issues at hand, and potential impacts of the study. We then provide suggestions for those who wish to do similar studies.

Introduction

One aspect of being an engineering educator is doing research, and a subset of that research may focus on engineering education. One research area with particular potential for having impact on engineering education is diversity. Diversity is a significant concern in engineering education, as evidenced by the numerous recent calls to recruit and retain more women and underrepresented minorities into engineering majors and professions^{1,2}. Discussions about the importance of meeting the needs of diverse students are widespread; however, there has been less discussion of how to define diversity, and how to actually go about studying diversity in meaningful ways. Given the lack of explicit guidance in this area, new engineering educators may benefit from examples of how their peers are thinking about diversity in designing educational research studies.

By encouraging educators to “think about diversity,” we hope to emphasize the idea that investigating issues of diversity in engineering education means more than simply tracking the numbers of underrepresented minorities or women entering and staying in engineering programs. Diversity needs to be considered broadly, and also in ways that recognize within-group differences as well as individuals’ identifications with multiple groups^{3,4,5,6}. Student diversity appears in many different forms – several of which may be present in the same student – and each type of diversity can greatly impact a student’s experience in the learning environment. As educators, we have a responsibility to rethink our own conceptions of diversity, consider what additional types of diversity might be playing roles in our classrooms, and investigate ways of addressing the salient diversity issues.

Some examples of how people are thinking about and studying diversity can be drawn from the work of engineering faculty who participated in an engineering education research institute. The Institute for Scholarship on Engineering Education (ISEE) is one element of the National

Science Foundation funded Center for the Advancement of Engineering Education (CAEE). The primary goal of ISEE is to cultivate a diverse community of engineering education researchers who can think and work across disciplines with the ultimate aim of improving the engineering student experience. A secondary goal is to formulate principles and models for advancing this scholarship community. To fulfill these goals, the ISEE team designed three year-long Institutes hosted by the University of Washington (2004), Stanford University (2005) and Howard University (2006). At each of these Institutes, engineering faculty and graduate students have learned research methods, designed and conducted research studies linked to the ongoing scholarship in CAEE, created resources for dissemination, and refined leadership skills.

The 2006 ISEE participants, or Scholars, were relatively new to engineering education research when they began their ISEE year. Eighteen Scholars were selected from a competitive, national pool of candidates based on the strength of each Scholar's application – including a proposed research project focusing on diversity issues – and the capacity of the proposed project to meet the ISEE goals of 1) contributing to engineering education scholarship, 2) enhancing learning and local change, 3) facilitating coherence and expansion of the existing community, and 4) demonstrating engineering education scholarship as a professional endeavor. They began their ISEE experience with an intensive, week-long workshop at Howard University during the summer of 2006, where they designed research studies focusing on issues of diversity in engineering education. Each Scholar came to the summer workshop with an initial research question, which was revised and refined over the course of the week. During the week the Scholars also developed research plans, including appropriate research methods and project timelines. The Scholars then conducted these studies on their home campuses throughout the 2006-07 academic year, with support from their fellow Scholars and the ISEE leadership team. Each Scholar chose a research topic and designed a study with relevance to his or her own campus, focusing on diversity issues that are salient in that particular context.

In this paper we provide three examples of the Scholars' studies in order to demonstrate some ways in which diversity can be conceptualized and integrated in educational research. The three studies discussed here were chosen because they represent a variety of ways of conceptualizing and investigating diversity. The researchers and their study settings are identified in this paper both to acknowledge their work and to make evident the contexts in which their studies take place. Key to the exploration of diversity is the recognition that context is crucial to the understanding of diversity issues. The types of diversity that are important to examine, as well as what those diversity categories really mean, are context-dependent. As such, the specific setting for each study is a critical piece of information for understanding the thinking behind each study design.

For each study, we discuss how diversity is defined, how the research question addresses the relevant aspects of diversity, how the chosen research methods facilitate in-depth understanding of the issues at hand, and potential impacts of the study. The three studies represent a variety of ways to look at diversity: 1) racial and ethnic diversity, 2) diverse academic pathways, and 3) learning style diversity. Each section begins with a discussion of the researcher's conceptualization of diversity, exploring the reasoning behind the decision to focus on particular diversity issues. The study's research question and methods, and the rationale behind the choices made, are then discussed. This organization parallels the process by which the researchers

designed their studies. They began by carefully considering the diversity issues most salient in their settings, then refined research questions and developed study designs to effectively address those issues.

The results of these studies are not discussed here. In some cases the data may not be completely collected and/or analyzed, and the findings of these studies are not the focus of this paper. Rather, this paper highlights the development of the study designs and the thinking behind the choices made in planning the studies. By making visible the processes involved in designing these studies, we hope that these examples will be useful models or guidelines for others who are interested in designing similar studies around diversity issues.

Study #1: Sharon Jones, Lafayette College

Conceptualizing Diversity

For this study, diversity is defined in terms of race and/or ethnicity, focusing on African American and Hispanic American students. Examining the experiences of students from these minority groups is appropriate and important in the study's context for many reasons. In a broad sense, this focus is important because it addresses the nationwide need to improve educational opportunities for underrepresented minorities. In 2003, Hispanic Americans and African Americans comprised 6.2% and 7.9% respectively of those graduating with an undergraduate engineering degree from U.S. colleges⁷, while the general population of the U.S. is comprised of approximately 14% Hispanic Americans and 12% African Americans⁸. Moreover, Chubin *et al*⁹ also reported that fewer than two in five (40%) minority first-year students who enter engineering graduate with an engineering degree. Clearly, diversity issues having to do with opportunities for underrepresented minority students are a major concern.

However, racial/ethnic diversity was not chosen as a focus for this study simply in response to the national concern. Focusing on African American and Hispanic American students is important and timely in this specific context because of the demographics of this four-year college's student population and the college's current efforts to recruit and retain students from these particular minority groups, and the fact that the college already practices many proven retention strategies. At this college, just 5% of the engineering majors graduating in 2006 came from minority groups. Within the college's engineering program, an estimated 25% to 50% of the African American and Hispanic American freshmen who start in engineering change majors by the end of their first year. This is much higher than the first-year attrition rate for all of the college's engineering students, which has been approximately 15% over the last ten years. Because of these trends, the college is currently engaged in a college-wide effort to increase the number of minority students who attend and graduate from the college, particularly in engineering.

As part of that effort, for the last five years the college has successfully worked with the POSSE Foundation as one way to enhance campus diversity in terms of both recruitment and retention. The POSSE Foundation is a non-profit organization based in New York that aims to 1) increase the pool of qualified diverse students ready for selective colleges, 2) increase those students' success at selective colleges, and 3) make campuses more welcoming for diverse students and

diversity in general¹⁰. The colleges in turn provide mentoring and financial resources for these student groups. Nationally, POSSE students have excellent retention and graduation rates. However, most students are not enrolled in engineering programs, and at this time there are no published studies specifically examining the POSSE program's success with retaining minority students in engineering and science majors. Conducting such a study is now possible, as the Class of 2010 at the college includes a POSSE cohort with several students who began the 2006-07 academic year as engineering majors and fall into one of the designated U.S. minority groupings: African Americans, Hispanic Americans, and Asian Americans.

It is important to stress that the decision to focus on engineering students from racial/ethnic minority groups was not made merely because of the national call to address the needs of underrepresented minority students. The national concern does create the larger context within which the study is set. However, the decision to focus on these particular students was deliberately made after a careful examination of the college's demographics and current diversity-related activities, which led the researcher to determine that this type of diversity was most salient in her setting. In addition, the literature shows that the reasons for attrition vary across different campus settings; therefore, the results of this focused study should be directly applicable to this particular campus context.

Research Question

In order to understand the experiences of the focus students, the researcher investigated the following research question: *What effect does an intensive, structured mentoring program (this college's POSSE program) have on the retention of first year engineering students from minority backgrounds?*

This question allows the researcher to focus specifically on Hispanic American and African American students in this college's engineering program, addressing the need discussed above. The question also positions the researcher to do a meaningful comparison across student groups within the setting; that is, POSSE and non-POSSE minority students. By setting out to investigate in broad terms "what effect" the program has, the researcher did not limit the study to preconceived expectations, but rather left room for unexpected discoveries. This openness is important in a study like this, which seeks to understand the experiences of students. The likelihood is high that some of those experiences may not be anticipated by the researcher, and it is often the unexpected findings that prove to be the most interesting and telling about the study subjects and their setting.

Research Methods

In this study, a grounded theory approach with purposeful sampling of the college's Class of 2010 is used to determine whether specific strategies included in the POSSE program improve the first-year retention of minority engineering students. Three groups of study participants were recruited from the following student populations:

- 1) Group A: Class of 2010 POSSE students who began the 2006-07 academic year as engineering majors and fall into one of the designated U.S. minority groupings (Asian Americans, African Americans, and Hispanic Americans).

- 2) Group B: Class of 2010 non-POSSE students who began the 2006-07 academic year as engineering majors and fall into one of the designated U.S. minority groupings.
- 3) Group C: Class of 2010 random sample of U.S. majority group students who are not members of POSSE and began the 2006-07 academic year as engineering majors.

First, quantitative information was collected in order to understand the background and current academic circumstances of the study participants. For each of the three groups, academic background measures were obtained from the College Registrar and Admissions Office. These data sources include the students' college admissions rating, high school GPA, SAT scores, and highest math course taken. Academic performance data were also collected for each group at the end of the first semester. These data represent academic integration factors such as GPA, academic major, and grades in first-semester math, science and engineering courses. Comparisons of these data were made across the three groups. The same academic performance data were collected for each of the groups at the end of the academic year, for further cross-group comparisons. These data helped describe and establish the "what" of this study context – who are these students, what backgrounds are they bringing with them to college, and what are their first-year experiences in this college's engineering program like?

To probe deeper into these findings and explore the meanings behind the numbers (e.g., the percentage of minority students leaving the engineering major), qualitative methods were used. A semi-structured survey was conducted with all three participant groups. The survey protocol was guided by existing surveys from previous student retention studies^{11, 12, 13, 14}. However, this study's survey goes further than previous protocols by also including questions regarding academic integration factors, social integration factors, and external influences. These additional questions were influenced by studies done by Tinto^{15, 16}, but were modified to address the particularities of this college's engineering context. The survey also included questions about the students' perceptions of how different groups of students within engineering interact with each other, in order to examine the role of student integration as a dynamic feedback process rather than an assimilation process.

By asking the students about this range of factors, the researcher was able to probe more deeply into the reasons behind the retention statistics. In addition to looking at whether the POSSE group's retention rate was higher, the researcher also sought a more complex view of the students' lives in order to better understand why they made the decisions they did. Based on evidence from previous research (e.g., Tinto^{15, 16}), the researcher had reason to believe that these particular factors might be involved in students' decisions to stay or leave the engineering program. The wide range of questions included on the survey made it possible to delve into nuances of the students' educational experiences and enrich the researcher's understanding of what was taking place in the study setting.

Potential Impacts of the Study

Since the start of this study, the college has taken steps toward addressing diversity in engineering education. For example, in the Fall of 2006, the engineering department heads held a special meeting about diversity issues. The undertaking of this study by this researcher has already made diversity issues more visible on her campus, which is an important starting point

for change. Information provided by this study about the experiences of POSSE and non-POSSE minority students at the college will help the college to better address retention issues for all of its minority students. In a broader context, since the experiences of POSSE students in engineering programs has not been studied previously, POSSE programs at other schools around the country will benefit from this study's findings.

Study #2: Jaime Hernandez Mijangos, Texas State University, San Marcos

Conceptualizing Diversity

In the second study, diversity is also defined along racial/ethnic lines, but this type of diversity is examined in combination with students' pathways into engineering. Specifically, the study focuses on Hispanic students who transfer from two-year colleges to a four-year university. The study subjects are first- and second-generation Hispanic students who have transferred from selected Texas community colleges to an engineering program at a four-year university in Texas.

Focusing on these two types of diversity in tandem is both important and appropriate in this context. Similar to the previous study, in a broad sense the emphasis on Hispanic students is situated within the national effort to improve the educational opportunities and experiences of underrepresented minorities. However, in this case it is appropriate to narrow the scope from all minority students to specifically Hispanic students because of the demographics of this university and the region within which it is located. This Texas university has a diverse campus community, with over 28% of the student body coming from ethnic minority groups. In 2006 the university's undergraduate student population was 21% Hispanic¹⁷. Statewide, Texas has an explicit interest in addressing the educational needs of Hispanic Americans, as illustrated by the Texas Higher Education Coordinating Board's (THECB) *Closing the Gaps* initiative, which includes the following goals for the state's Hispanic student population: (1) Increase the higher education participation rate for the Hispanic student population of Texas from 3.7 percent in 2000 to 4.8 percent by 2010, and to 5.7 percent by 2015; and (2) increase the number of Hispanic students completing bachelor's degrees, associate's degrees, and certificates to 50,000 by 2010, and to 67,000 by 2015¹⁸. At many universities the inclusion of students from multiple minority groups would be critical in order to adequately represent the student population. However, at this university, the high percentage of Hispanic students, paired with the statewide demographics and priorities, makes a focus on this particular group a logical choice. This narrowed focus also makes it possible to look at factors that may be salient for Hispanic students but would not have the same effect on the experiences of students from other backgrounds.

The second facet of diversity utilized in this study – nontraditional pathways into engineering – is also significant. Nationally, it is important to understand and address the needs of students who transfer from two-year colleges to four-year universities, since a large number of students enter engineering programs via this pathway¹⁹. This university is no exception, with a large percentage of students entering as transfer students from two-year colleges. However, rather than including all of the university's transfer students, this study specifically looks at transfer students of Hispanic descent, thus acknowledging that concurrent membership in these two groups – being Hispanic and being a transfer student – creates a unique set of experiences. The population of students with these combined circumstances is substantial: in 2005, over 23% of

the university's newly enrolled Hispanic students transferred from Texas two-year colleges¹⁷. It is crucial to look at how the intersection of these identities affects the educational experiences and pathways of these students. It would not be sufficient (or realistic) for this study to attempt to make generalizations about all underrepresented minorities, all Hispanic students, or all transfer students. Therefore, the researcher has deliberately and thoughtfully narrowed his focus to Hispanic students who transfer from selected Texas two-year colleges to this university.

Research Question

Having determined the importance of examining the experiences of this particular student population, the researcher set out to answer the following question: *What are the most meaningful learning/developmental experiences that motivate Hispanic students to transfer from selected Texas community colleges to a four-year engineering program?*

This question effectively targets the types of diversity delineated above, allowing the researcher to focus on the chosen segment of his university's student population. The question also helps the study move beyond simply describing the situation, and seeks a deeper understanding of the "why" and "how" behind the "what." The fact that a significant number of Hispanic students in the university's engineering program transfer from Texas two-year colleges has already been established. What is less clear is why those students follow that particular pathway. Examining the learning and developmental experiences operating behind their choices and progress along that pathway provides one interesting lens through which to understand this phenomenon.

Research Methods

In order to investigate these issues, the study design includes both quantitative and qualitative research methods. First, a large-scale questionnaire was used to gain a broad understanding of the transfer student experience. The researcher used the Community College Experiences Questionnaire, which is a "student self-report instrument that provides information about students' academic and social integration into the community college setting"²⁰. The questionnaire was administered to students falling into the category discussed above: Hispanic American students who transferred from selected Texas two-year colleges to this university's engineering program. The results of this questionnaire provided a broad picture of the experiences of the target student population, which became the foundation for the next phase of the study.

Next, to dig deeper into the specific experiences of the study population, focus groups were conducted. These focus groups brought together small groups of students from the target population for guided discussions with the researcher. These discussions let the researcher probe more deeply beneath the surface of the students' academic pathways, exploring which learning and developmental experiences had been meaningful and why, and how those experiences affected their motivation to transfer to the four-year engineering program. Although the discussions were guided by the researcher, the focus group format allowed the students to speak at length and describe their thoughts and experiences in their own words.

Potential Impacts of the Study

The findings of this study should have an impact not only on this university's campus, but nationally as well. Information provided by this study about why and how Hispanic students transfer from two-year colleges to this university's engineering program will inform the university's efforts to support these students during their time on campus, and should help improve recruitment and retention efforts as well. More broadly, little research has been done to date on the factors involved in transfer students' academic pathways, and this study will make an important contribution to that body of knowledge.

Study #3: Rebecca Bates, Minnesota State University, Mankato

Conceptualizing Diversity

The third study examines a different type of diversity, which is appropriate for the study's context. Here, student diversity is defined as differences in learning styles which may or may not be addressed in a typical college classroom. At this Midwestern comprehensive university with both engineering and engineering technology programs, the student population appears to be quite homogenous, primarily male, primarily white. In teaching the students, however, it is quite clear that the students are very diverse in their learning styles (as opposed to aptitudes and abilities which also vary). The investigator's experience with teaching a single class to students in both engineering and engineering technology was the driving force for designing a study that examines learning styles in this context. When students learn differently than faculty teach, it is too easy to write the students' abilities and aptitudes off. Thus, studying the diversity of learning styles may be useful for individual students and their learning, and may also be useful for improving teaching styles at this location.

Research Questions

The key research questions addressed by this work are:

- *What are the relationships between learning styles and clustered major groups (engineering, engineering technology, computer science, IT and nursing), gender and length of time in college?*
- *In order to debrief students and make knowledge of their learning style useful for them, what information about learning styles will be most useful for (and read by) participants?*

These research questions address the issue of diversity of learning by first quantifying an issue that has not been investigated in this setting, and then qualitatively examining what information about learning styles will be helpful for students interested in improving their own learning. As more detailed information is available about the distribution of learning styles at this university, the quantitative information may be useful in helping professors develop their teaching styles to better match student learning styles. The qualitative information will help provide students with truly useful information about their learning. Since a goal of the university, college and ABET is to graduate students who are lifelong learners, this can help create awareness of their own learning processes.

Research Methods

The quantitative portion of this study is in the form of a survey that incorporates the Felder Learning Style Inventory²¹, as well as basic demographic questions that include information about such things as the student's GPA, major, parental education level, and length of time in college. The learning style inventory results in four measures showing preferences between active/reflective, sequential/global, visual/verbal and sensing/intuitive. The results of the survey will be used to get an agglomerative measure of the learning style distributions that can be compared across different demographic factors. A subset of students who take the survey will be asked to give feedback on informational materials as well as to reflect on their learning experiences before and after knowing about their own learning style.

The qualitative portion of this study is done with focus groups and individual interviews, targeting upper-division students so that their experience with learning can be used for reflection. Questions in the focus groups and interviews will address possible handouts and means of information transmittal and will gather information about student experiences with learning, both positive and negative. Focus groups and interviews will be used to 1) discover which information about learning styles is best suited to the students at MSU, and 2) whether students feel as though this knowledge has changed their approach to learning. The results will be fed back into the study by changing the amount or focus of information about learning styles that is given to participants.

Potential Impacts of the Study

As a new project, it is hoped that this study will yield interesting results. However, it is also hoped that this will be the pilot study for a longitudinal project that will allow examination of learning styles and retention rates. If students who have different primary learning styles are always taught in ways that are less comfortable for them, they are going to feel less like they belong to the community of engineers/engineering students.

Discussion

The three studies described above provide examples of how some researchers are conceptualizing and investigating diversity in engineering education. For other engineering educators who may wish to conduct similar studies of diversity issues, it is important to view these examples not necessarily as models to be replicated, but as illustrations of the importance of context and the critical need to rethink assumptions about diversity. The Scholars participating in the 2006 ISEE were challenged to think about diversity issues in their own campus contexts, and then critically examine their original conceptions in order to push their thinking in new directions.

All three studies examine types of diversity that are frequently discussed as national concerns: underrepresented minority students, transfer students, and learning styles. Those national concerns do play roles in the larger setting within which the studies are situated. However, these researchers did not design their studies based solely on national trends or broad assumptions about which diversity issues need to be addressed. They went a step further by deepening their conceptions of diversity and tailoring their diversity focus to their specific contexts. What is

important to note is the methodical way in which the researchers considered the particular needs and issues present in their settings, deliberately chose to investigate specific types of diversity, and justified those choices with data about their study settings. They then designed studies that allowed them to investigate diversity in ways that were most salient on their own campuses. As illustrated in the examples above, diversity issues are very context-dependent, and it is crucial that conceptualizations of diversity emerge from the study setting, rather than being imposed from outside.

The researchers were also very deliberate and careful in the development of their research questions and study designs. In each case, the question was constructed in a way that let the researcher describe what was happening in the setting and then probe deeper to understand why or how certain things were taking place. Because of the complexity of diversity issues (not to mention the complexity of human subjects), it is often more informative to be open to unexpected findings than to “test” for specific results. In each study, both the research question and research methods allowed the researcher to first assess the study context, describe the situation, and back up that description with data. The researcher was then well-positioned to dig deeper and develop a richer, more meaningful explanation of why and how certain things were happening in the setting. By gaining deeper understandings of the workings behind the visible events, it is hoped that we can better understand the causes behind the effects and thus take more effective steps toward change.

In summary, the following suggestions may be helpful for those wishing to embark on this type of research:

- Rethink your definition of diversity. Even if you have already put considerable thought into issues of diversity, it can be beneficial to take another critical look and ask what other types of diversity might be playing roles in your setting. You might pose questions such as the following as you construct your working definition of diversity:
 - What are the important diversity issues in *your* context?
 - How are those issues situated within national (or global) diversity concerns?
 - Who are your students, and what factors impact their learning experiences?
 - What types of diversity might be invisible, yet significant, in your setting?
- Formulate a research question that goes beyond exploring the “what” (i.e., what is happening in your university/college/classroom context, demographic statistics, etc.), and gets into the “why” and “how.” Allow for a certain amount of openness in order to make it possible to discover the unexpected. This can be done by phrasing the question in terms of “what effect” or “what are the experiences,” for example, rather than asking “yes” or “no” questions.
- Consider research methods that can portray the landscape and describe your context, and also dig deeper to understand the experiences of the people involved. Quantitative measures can be very informative about what is happening in your context, which students are doing what, etc. Then, to gain a deeper understanding about the reasons, thinking, and motivations behind those facts and figures, certain qualitative methods may be useful. For example, interviews, surveys (especially those with open-ended

questions), and focus groups all provide opportunities for study participants to express their thoughts in their own words.

In addition to the above recommendations, other suggestions that apply generally to educational research are also important, especially when studying diversity issues in engineering. For example, the following suggestions emerged from the 2006 ISEE Scholars' experiences:

- Know your target population. This may seem counterintuitive, if the goal of your study is to understand the target population. However, going into the study as knowledgeable as possible about the issues and the people involved is advantageous, and will better inform your research question. One strategy is to work with a student from the target population early in the study design process, to assist with the development of protocols, subject recruitment strategies, and so on.
- Become familiar with your institution's Internal Review Board, and begin the Human Subjects approval process early. Studying issues of diversity necessitates working with human subjects, and depending on the institution, the approval process can be lengthy.
- Read the relevant body of knowledge about the diversity issues on which you are focusing, including existing theories or models and their critiques, both within and outside of the engineering literature.
- If possible, pilot test interview or survey protocols, whether you are adapting an existing protocol or designing your own. Because each context and each student population is different, questions that worked well in one setting (or for other researchers) may not yield the same type of results in your setting.
- Get buy-in from your department, school, and/or institution. Diversity issues can be sensitive, and having campus-level support and buy-in in advance will make it more likely that your findings are disseminated and lead to impact. This research is not just about knowledge; rather, it is about change, and meaningful change cannot happen unless researchers work with their campuses.

Studying diversity is a complex and important undertaking. Because of the context-dependent nature of diversity issues, it is difficult to provide a simple set of guidelines or steps to follow. However, our hope is that the above examples of how diversity has been studied in three specific settings, as well as the suggestions gleaned from the experiences of the ISEE Scholars, will be useful for other engineering educators. We hope to see more engineering educators investigating diversity issues in their own settings, and working to improve the educational experiences of engineering students.

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