Excellence in Engineering Education: Views of Undergraduate Engineering Students

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ABSTRACT

The purpose of this study was to understand the views and perceptions of engineering undergraduate students on engineering education. The method of content analysis was used to analyze the language used by engineering undergraduate students, and to extract the underlying common factors or perceived characteristics of "Excellence in Engineering Education." These common factors were then used to identify and compare the similarities and differences in views between engineering students and perspectives from three types of stakeholders in the field. Forty-seven undergraduate engineering students (17 females and 30 males) participated voluntarily in this study to answer four individual questions and ten group questions. The results showed that students strongly emphasized the importance of their own roles in the educational system and the value of instructional technology and real work examples in enhancing the quality of engineering education. The implications of the research results on excellence in engineering education are discussed.

Keywords: content analysis, excellence in engineering education, focus group

I. INTRODUCTION

During the 1990's and continuing today, there has been a significant movement towards understanding the issues that may affect the quality of engineering education. According to the National Academy of Engineering and other organizations, such as ABET, Inc. [1], many universities around the world have been making major efforts to: (1) recognize the challenges faced by engineering education programs, and (2) make changes to achieve what many are calling "Excellence in Engineering Education." As one example of the programs developed recently, in 2002 the National Academy of Engineering launched the Center for the Advancement of Scholarship on Engineering Education (CASEE) [2]. Its purpose is to understand at a deeper level what should be taught in engineering and how to teach students by recognizing how they learn. Through its research and activities, CASEE defines specific and measurable outcomes to challenge itself and the engineering community to achieve its goal of excellence in engineering education. CASEE defines excellence in engineering education in terms of its effectiveness, engagement, and efficiency.

Along with institutional goals as standards of excellence, research in engineering education shows that an integral part of the process is providing undergraduates with opportunities to develop individual characteristics and skills that will positively impact the students' future career. Rugarcia et al. [3] and Felder, et al. [19] both state that an integral part of an engineer's profile is the development of knowledge, skills, and attitudes that dictate the goals toward which students' skills and knowledge will be directed. From the perspective of faculty, Fromm [4] defines a detailed list of characteristics which future engineering graduates should possess to become leaders of the profession, including a strong foundation in basic sciences, mathematics and engineering fundamentals, and the capacity to apply these fundamentals to a variety of problems, among others.

Another example is the Millennium Project [5] at the University of Michigan, which is a research laboratory designed for the study of the future of the American universities. The mission of this project is to "provide an environment in which creative students and faculty can join with colleagues from beyond the campus to develop and test new paradigms of the university." The Millennium Project proposes some key characteristics of education in a society of learning, including being learner-centered, affordable, supportive for lifelong learning, a seamless web, interactive and collaborative, asynchronous and ubiquitous, diverse, intelligent, and adaptive. They state that in the process of transforming the university, a balance should be achieved: among missions (teaching, research, service), among disciplines (liberal education, academic disciplines, and professions), among undergraduate vs. graduate vs. professional education (e.g., education vs. training), among sciences vs. humanities, and among life sciences vs. everything else. Ehrmann [6] summarizes the goal of engineering education as follows: "what undergraduate students need to learn or develop in the future is a combination of certain knowledge, skills, and wisdom."

In the design of engineering systems and processes, the concept of user-centered design is widely used. This approach involves the user early in the design and evaluation of the system and its processes. If we analyze our educational system and its goals from a human factors perspective then we would understand the importance of involving our students, which are the "users" of the system in the development and evaluation of our educational environments. According to the National Survey of Student Engagement (NSSE) 2000 report [13], students learn more when they are intensely involved in their education; this is also seen in our classrooms where student-centered instruction [12] is playing a significant role.

Students are playing a significant role in shaping our learning environments, but this seems not to be the case when it comes to policy making. This is why it is important to ask whether the views, perceptions, and definitions of our undergraduate engineering students are aligned with the views proposed by different stakeholders in the field [2-6, 10, 12] on what is considered to be excellence in engineering education.

Few studies have looked into how undergraduate students define excellence in engineering education. Our study presents a thorough list of characteristics that define excellence in engineering education from the student's perspective with the objective of developing a better understanding of these views and perceptions. In this paper we present the responses of our sample to four individual questions focusing on excellence in engineering education, followed by the responses to a focus group discussion. Student views are presented on topics including: student and professor roles, educational technology, goals and challenges of teaching engineering, and effective teaching methods, among others. The method of content analysis and keyword frequency count will be used to analyze the language used by engineering undergraduate students and extract the underlying common factors from the individual and focus group questions. Furthermore, we identify the similarities and differences in views on teaching engineering between engineering students and a random sample of three types of stakeholders in the field.

II. Research Methods

A. Focus of Study Questions

The questions addressed in this study were inspired by the literature on engineering education from sources like ABET [1], the National Academy of Engineering [2], and work by Felder and colleagues [3, 12, 19–21, 23]. We analyzed the literature and identified common threads, then developed a series of questions to gain insights into the perceptions and views of our undergraduate engineering students. For example, the literature on excellence in engineering education stresses the importance of knowledge and skills [2, 3, 5, 6, 10]. Based on these examples from the literature we wanted to understand if the students perceived as part of their goal to learn knowledge and skills. With this goal in mind, we asked our students individually to describe their role in the college of engineering and to discuss as a group the goals of teaching engineering, and the types of skills and attitudes they need to learn.

B. Participants

Forty-seven University of Michigan undergraduate engineering students (17 females and 30 males) participated voluntarily in this study. The participants replied to ads and e-mails sent to all students in the college of engineering. To participate in this study, undergraduate students had to be 18 or older and enrolled in at least one engineering course. Each participant attended one of 12 focus groups, which lasted one hour. Each focus group had between three and eight participants of both genders. Each participant received a monetary compensation of $10.00 for their time.

C. Procedure

The participants were greeted individually and asked to read and sign a consent form to participate. The participants were first asked to answer four individual "brainstorming" questions, one question at a time. They were asked to write on blank sheets of paper 10 words or phrases that came to their mind when they think about or hear a specific phrase. The phrases were: (1) excellence in engineering education, (2) educational technology, (3) student's role in the engineering college, and (4) professor's role in the engineering college. The participants had three minutes to write down their responses for each phrase individually, and then return the sheets. Only for question one (phrase of "excellence in engineering education") were the participants asked to rank all the words and phrases they wrote according to what they felt was more important for them. After answering the individual questions, the participants were asked to participate in a focus group discussion on ten questions, which were asked by the experimenter and the responses were audio taped for transcription purposes.

Content analysis was the method used to analyze the data. This method is a research technique for analyzing text data and making replicable and valid inferences from data to their context [7]. Liu [8, 9] applies content analysis within the context of engineering aesthetics, as a procedure to analyze selected texts with the aim of obtaining useful insights into a research question and make inferences about their substantive problems. In this study, keyword frequency count was the content analysis index used to summarize the data. Keywords are words extracted from each participant's responses and used to summarize the answers. The data are summarized by showing the number of occurrences of keywords for the individual questions, and how these keywords were grouped into categories. As part of the analysis of the results, responses to the individual questions and group discussion questions were analyzed by a group of five trained assistants. Each assistant individually assigned a keyword to each response for the individual or group discussion question. The keywords assigned by each trained assistant were then compared among the five assistants to choose the keyword that best described each answer. In the event there was a disagreement between the assigned responses, a consensus was reached between the five assistants after a discussion on the best keyword that would represent the participant answer.

III. Results

A. Individual Brainstorming Questions

Keyword frequency values are shown below, for each of the four individual questions. The number shown next to a keyword represents the number of times the specific keyword was recorded. If a keyword is not accompanied by a numerical value, then that keyword was not repeated among the different participants more than once. Ideally for each question there should be 470 responses, if each participant could write 10 responses for each of the questions during the allowed time.

1) What is Excellence in Engineering Education? This question generated a total of 410 words or phrases among the 47 participants, which were grouped into the following 14 categories: characteristics or definitions of excellence (n = 122), individual or personal characteristics (n = 58), general examples of excellence (n = 47), personal and professional skills (n = 39), resources (n = 39), professor characteristics (n = 21), knowledge (n = 18), need for examples or real life application (n = 16), community (n = 15), hard work (n = 13), hands-on (n = 11), cost (n = 5), grades (n = 4), and degree (n = 2). Each participant ranked their own responses for this individual question from what they considered to be most important to the least important word or phrase. Table 1 presents a summary of the responses ranked as number 1 by the participants, when describing what is more important in excellence in engineering education. The participants of this study defined or characterized excellence in engineering education with the following keywords:

> Accredited, accurate, analytical, applied and hands-on, challenging, changing, clear, commitment, communication, competitive, complex, comprehensive, constructive, cost-effective, current, demanding, detailed, different, diverse, efficient, ethical, hard work, hybrid, important, informative, innovative, integrative, interactive, international, intuitive, involved, leadership, mathematics, meaningful, modern, multidimensional, multidisciplinary, new, personalized, practical, precise, preparing for the future and long lasting, pressure, working towards prevention and safety, quality, reliable, reputable, involved in research, rewarding, robust, satisfaction, science, selective, simple, specialized, stimulating, technical, understandable, unique, useful, varied, and well rounded.

From the total number of responses we can infer that this was an easy question for the students, since they were able to generate meaningful and insightful responses quickly.

2) What is Educational Technology? When the participants thought about educational technology they generated a total of 413 words or phrases that were grouped into eight categories, including: tools (n = 126), general characteristics of educational technology (n = 115), software (n = 56), specific examples of educational technology (n = 55), Internet (n = 42), application of educational technology (n = 11), research (n = 6), and internships (n = 2). The general characteristics category includes all the words and phrases that students used to define technology. The participants described educational technology as:

> Advanced, different from lecture, engaging, hands-on, providing independence, interactive, could be used as help, increasing and facilitating knowledge, enhancing level of understanding, being up-to-date, and varied.

Interestingly enough, students perceived internships and research as tools or vehicles of educational technology. For the most part, the participants' answers suggested either physical examples of technology or ways in which it is used. The answers given by the participants reflect a general misconception of educational technology, which is not only multimedia and audiovisuals, but it is a process of teaching and learning in itself.

3) What is the Student's role? Thinking about themselves and their role in school, the participants generated 199 words or phrases, which were grouped in 19 categories. On average, each student was able to write about four words or phrases. The number of responses is important as it suggests that this was a difficult question or the allowed time was not enough for the participants to generate a list of 10 phrases or words. According to the participants, their role in the school was to be or to do certain things which are referred to as self characteristics (n = 38), to learn (n = 34), be a student (n = 24), contribute (n = 23), prepare for the future (n = 16), to mentor others (n = 11), participate in extracurricular activities (n = 9), develop skills (n = 7), represent their race or college (n = 7), pay tuition (n = 5), earn a degree (n = 4), make friends (n = 4), do research (n = 4), have no impact at all (n = 3), compete (n = 2), network (n = 2), experience college (n = 2), make good use of resources (n = 2), and maintain good grades. "Self-characteristics" was the keyword used to group all the words or phrases that the participants used to describe themselves within their role, for example:

> Client, collaborator, colleague, consumer and customer, critic, a dependable teammate, designer, employer, engineer, and members of the engineering community.

Students also thought that their role was to evaluate staff and professors, feel significant/insignificant depending on size of class and attitude of professor, go through the process as "being on a conveyor belt going through some education factory," play sports, grow and be a better person, gain independence, interact with professors and graduate student instructors, "become better rounded," represent a minority, observe, participate, "live up to the high standards of the school to keep its reputation," "make parents/family proud," "prove I can make it," be a speaker or teacher, ask questions, use resources, volunteer, work, and write.

From the study we observed the participant's eagerness to answer, so the small quantity of responses for the question of student's role and professor's role (next question) should not be interpreted as an indifference to the questions or lack of importance.

Category	Participant Responses
Characteristics of excellence	Time commitment, diverse, education for the future, innovation, intuitive, mathematics, personalized instruction, program quality, understandable
Community	Excellence in people/students and peers, Student-teacher ratios
Cost	Money
Degree	Degree/diploma and obtaining an engineering education
Examples of excellence	Students achieving excellence by doing well in classes/professional career/beyond formal schooling and finding internships
Hard work	Hard work and effort
Hands-on	Hands-on
Individual characteristics	Creativity, experience, honesty, motivation, interested students and willing to learn
Knowledge	Oriented to improving current knowledge
Need for examples or application	Real life applications
Personal/ professional skills	Problem solving, networking, responsibility, visual skills and teamwork
Professor characteristics	Good and responsible professors
Resources	Up-to-date learning

Table 1. Summary of the responses ranked as number one for the "excellence in engineering education" question by category.

4) What is the Professor's role? We gathered 216 words or phrases and 23 categories were generated to group the responses and keywords. These categories are related to characteristics of the professors and their role in the college, including: to teach (n = 29), to help (n = 22), personal characteristics (n = 20), to work in research (n = 16), receive comments from students' opinions (n = 16), mentor (n = 15), prepare (n = 13), motivate (n = 9), understand (n = 8), be a model/inspiration (n = 8), encourage (n = 7), facilitate (n = 6), explain (n = 6), be available (n = 6), share information/knowledge (n = 7), learn (n = 5), educate (n = 5), enforce (n = 4), grade (n = 4), develop personal relationships (n = 3), create tests/homework (n = 3), contribute (n = 2), and be up-to-date with real world and technology (n =2).

A comparison of the four individual questions is shown in Table 2. The words "students," "learning," "work" and "education" were the most commonly used keywords among the individual questions. "Teaching" and real life or "real world" were common words that appeared in the questions about excellence, technology, and professor's role. "Resources" was the only word shared between excellence in engineering education and educational technology. Possibly in the context of educational technology as a resource, and resources playing an important role in determining what is considered excellence in engineering education. "Help" and "knowledge" were two words that appeared in the responses of participants to the questions of student's and professor's role in the college. The keyword "help" for the question concerning the student's role was used in the context of helping others (n = 9), helping school, just help (n = 5), and helping themselves (n = 3). For the question concerning the professor's role the word "help" was used in the context of helping students to learn and acquire knowledge (n = 6), facilitate growth, help with questions outside classroom (n = 3), provide office hours (n = 4), help develop skills (n = 2), help through e-mail and research, and help with career and when needed (n = 3). In Table 2, the uses of the keyword "make" suggest actions, which is not surprising because as participants are asked about roles, they will certainly need to talk about what it is that they need to do, which involves an action. Participants referred to the word "make" in terms of making human connections happen (friends and contacts), completing a degree, and contributing. From the participants' views of the professor's role, the word "make" was used in the context of understanding (make understandable), make adjustments, be aware, and make tests. Many of the usages were related to the act of "making things happen for students" (unidirectional), which is different from the participants' perspective which took the viewpoint of making things happen for themselves and others, as a bidirectional link.

	Educational Technology	Student's Role	Professor's Role
Excellence in Engineering Education	students technology work teaching resources	students learning education work engineering	students learning education work teaching real world professors
Educational Technology		students help work	students teaching real life work
Student's Role			students learning education work classroom help knowledge make

Table 2. Summary of the shared words used in answering the individual questions, comparing two questions simultaneously.

B. Focus Group Discussion

During the focus group activity, the participants answered ten questions that were based on topics found in the literature [3, 6, 20–24]. The focus group questions were: (1) What are the types of interactions between students and professors? (2) What are the methods used to present information, and how would students like information to be presented? (3) What is the task of students in the classroom and what would students like to do in the classroom? (4) What are the current challenges in the teaching environment? (5) What are the goals of teaching engineering and what types of skills and attitudes do students need to learn? (6) What are the student experiences with alternative teaching methods? (7) What teaching methods do students feel work in the classroom? (8) How can a professor make students feel comfortable in the classroom? (9) How do professors learn? (10) What are students' opinions on course evaluations? The results for each of the questions are shown below.

1) What are the types of interactions between students and professors? The focus group participants mentioned that interactions between students and professors were an individual choice. Students suggested that interactions occur through electronic mail, office hours, and feedback obtained through graded homework. They perceived interactions were more likely to occur when the class is "not formal," when the students feel comfortable, when the professors are more approachable and encourage participation, when professors are "connected to the students making sure that students understand each step" of the lecture and class material, and when students get the opportunity to have a more personal relationship with the professor. Another type of interaction occurs when students work in research projects with professors. A few participants mentioned that "PowerPoint use in the classroom is a method that decreases interaction between students and professors," and "some times addressing questions in class delays the class and some questions should be dealt with after class."

These comments suggest that students are concerned with the types of interactions and the barriers that exist between students and professors. These barriers could be technological, environmental, as well as personal.

2) What are the methods used to present information and how would students like information to be presented? The board, PowerPoint, handouts, overhead and transparencies, examples/applications, lectures, Web sites, projects and presentations, interactive activities, stories, anecdotes, general questions asked in classroom, and videos, were mentioned as common methods used to present information in the classroom. Occasional e-mails are used to communicate corrections and announcements to students outside the classroom.

Students emphasized that they would like information to be presented through examples, demonstrations, stories, Web sites, notes, any form of visual display, handouts, use of group work to write papers, competitions, and oral presentations. Even though some of these methods are currently used in the classroom, they were mentioned again by the students thus emphasizing their importance. Students like the traditional method of using the board and overhead transparencies and having an interactive teaching style. They said:

- Using the board or overhead transparencies, "help students to see what the professor is writing, making it easy to see the progression of ideas," because "when using the board, professors tend to explain more than just going over the material." Further, when students write down the information themselves, "it's easier to remember, instead of just looking at it on a slide."
- Having professors ask questions in class "makes you think and process the information they are actually telling you."

Students also expressed interest in new technologies, including:

- Using instructional technology like the personal response systems to "ask students questions in class, collect responses, and then provide immediate feedback."
- Provide videos of the class lectures to review at home and movie clips to explain and demonstrate concepts.

The use of PowerPoint in the classroom received negative responses in general. For example, participants said that PowerPoint "appeals to only one type of learner, is hard to read and makes professors skip steps when explaining," having "dimmed lights in classroom makes students feel tired," and having "laundry lists of items" in a slide makes professors "stay too long at one slide and it gets boring." Outside the classroom, however, Power Point presentations may have great value when the presentations are made available online to assist student learning. This point is relevant as many universities are trying to develop distance learning courses as well as digital libraries of all the courses offered on campus. These materials could be used by students to complement class material and allow students to go deeper into the content.

3) What is the task of students in the classroom and what would they like to do? Participants agreed that their primary task in the classroom was to take notes, participate and ask questions, pay attention, follow the professor, highlight concepts, learn, and "try to stay awake" when they "feel bored because there is nothing new."

When students were asked what they would like to do in the classroom, their overwhelming responses were:

- see more application and examples and less lecturing
- participate in smaller classes, and increase interaction
- discuss homework problems in class as well as work more problems in class
- have a balance between notes and lectures, and show visual aids and examples of the real world application of what students learn in the classroom

These responses suggest the idea of active learning in the classroom and a shift from lecture-based courses to student-centered, application-based courses.

4) What are the challenges in the teaching environment? The common challenges reported by the participants of this study were: keeping students focused, motivated and interested, having a proper class pace, making the material as understandable to the student as possible, trying to make science available in common layman terms so that the society and children could understand, professors having better time management skill to balance research and teaching, and making both classes and the university environment more multidisciplinary. Other challenges mentioned by some of the participants include making education more affordable, dealing with limited resources, the professor's teaching attitude and accessibility, a more flexible curriculum with more opportunities for internship and practice, language issues and requirements, retention of students, and the understanding of student learning styles.

5) What are the goals of teaching engineering and the types of skills and attitudes that need to be learned? The participants reported that one of the main goals of teaching engineering was to develop a basic knowledge and developing skills. The skills mentioned more often were problem solving, critical thinking, teamwork, communication, interpersonal relations and people skills, creativity, discipline, responsibility, prioritizing, time management skills, writing skills, and applying technical knowledge, ethics, and theory in the learning process.

As part of the goals of teaching engineering, the literature suggests [3] that there is an attitude that is taught along with skills. Students in ten of the 12 focus groups suggested that indeed there was an engineering attitude being taught. This attitude includes accepting mistakes, having common sense, ethics, high standards, understanding that there is not always a right answer, being flexible, and having an open mind. From the student standpoint, patience, confidence, self trust, discipline, and persistence are other attitudes that students learn as engineers. Only two of the groups had different perspectives. One of the groups interviewed suggested that they did not believe teaching a certain attitude was part of the goals of teaching engineering. The other group suggested that attitudes are not learned from engineering education but students are helped to create their own attitudes. Certainly this is a topic that needs to be studied in more detail.

6) What are alternative teaching methods? The common experience reported by the study participants was group work, followed by laboratory experiences, hands-on activities, and distance learning. However, many students also mentioned that "seating arrangement in big classrooms makes it difficult to work in groups," and working in groups is time consuming. Also group work is seen from the perspective that "it takes time away from class, and sometimes is done too soon after the material is introduced." These concerns are similar to concerns of faculty on the issues related to alternative teaching methods, specifically with active learning exercises. Students suggested including alternative teaching methods in the course schedule or syllabus. This is important as students believe that if they know about the activity and understand the purpose behind it, they would feel more motivated and engaged. Other methods suggested as alternative teaching methods were games, having in class presentations, using individual response systems (example of instructional technology), undergraduate research opportunity programs, use of movies and demonstrations, teaching Web sites, learning in mini-sessions, and explanation diagrams of lecture structure and organization before giving all the details to students.

Students interviewed repeated and emphasized the use of examples and real life applications as examples of alternative teaching methods, along with upper level courses like senior design, and teaching different view points of approaching a situation without imposing one way.

7) What are teaching methods that work in the classroom? Providing examples/applications is an effective teaching method, followed by presenting information in both concrete and abstract ways, clear objectives, and recaps of information taught at the beginning or end of class are also methods that work. Students value when professors use interactive methods that break the monotony, when professors ask for questions at beginning of the lecture, when they teach using application versus theory, and when they are organized and provide space for students to mentor and help each other. Also when professors are excited about the class, acknowledge things that are difficult and simplify the material, "feel the audience" to see if students are following the lecture, and provide students with "time to soak" or time to let the newly presented material "be absorbed." Also participants liked when breaks are given in classes that are more than two hours long, when students are engaged, when professors move around in the classroom, and when a comfortable environment is created.

8) How can a professor make you feel comfortable in the classroom? The answer that participants mentioned most often was "know my name." They also agreed that a professor being approachable, available, and willing to meet made a great difference. Not only explaining simple assumptions made students feel more comfortable, but answering questions constructively and anticipating questions made a great difference. Participants also mentioned that they liked when professors approached students as equals and when they have a sense of humor. Participants agreed that professors should try to:

- be supportive to undergraduates
- "feel the audience"
- be excited about what they are teaching, along with keeping students engaged
- get in the students' position
- make mistakes and show how to fix them, allowing themselves to be more human
- be genuine about wanting to interact more with students
- greet students in the hall
- smile more often
- have graduate student instructors or teaching assistants come to class and interact with students

In general, the participants agreed that most of the comfort issues had to do with the professor's personality and demeanor in the class.

9) How do professors learn to teach? Common ideas expressed by participants on how professors learn to teach were the following:

- from student feedback and evaluations
- from their peers
- seminars, workshops and conferences
- trial and error
- sitting at other professors' lectures
- experience and graduate school
- experimenting
- learning from research
- videotaping lectures to get feedback

Most participants do not feel learning was a concern, as "professors learn because they have to and it is a requirement for teaching," although some participants feel some professors may not have a strong motivation to learn to teach. These insights provided by the students are important and relevant as we can see that students know that most faculty members have no formal training in teaching. It is shameful to see that students believe that faculty learn to teach by "trial and error" and experimenting in the classroom.

10) What is your opinion on course evaluations? Although course evaluations were frequently mentioned by the participants as a way for professors to learn to teach, it is also one issue with mixed feelings. While many participants believed course evaluations are important, they also agreed that course evaluations were done too late in the process and suggested mid-semester as a better time. One of the common remarks of the participants was that they did not know what the professors and the universities do with the evaluations after they were completed, particularly when there is a "high turnover of professors." Some of them also mentioned that they themselves lack motivation to participate in evaluations, since they would not benefit from the evaluations directly after having completed the course.

C. Views of Stakeholders and Undergraduate Students on Engineering Education

Table 3 shows a comparison of the results obtained from this study and three highly regarded perspectives taken from three types of stakeholders in the field. These stakeholders are represented by one educational researcher [4], a university-based project [5], and a national program [2]. Words in **bold** highlight the similarities between study results and researcher views. Only those common words were highlighted in the text. A detailed study of the different perspectives shows that there are many similarities between them but the language used varies, thus allowing the findings to be interpreted in many ways. For example, the participants in the study described excellence in engineering education as multidisciplinary; while other perspectives describe excellence as being interdisciplinary [4], collaborative [5], and converging with other relevant non-engineering disciplines [2]. The differences in interpretation and terminology present a barrier that may hinder the communication in the field between researchers, programs, and university-wide projects. Few studies have looked into how students define excellence in engineering education. Our study presents a thorough list of characteristics that define excellence in engineering education from the student's perspective.

IV. Discussion

A. Individual Brainstorming Questions

As discussed earlier, research literature on excellence in engineering education stresses the importance of knowledge and skills [2, 3, 5, 6, 10]. It also includes institutional outcomes such as engagement in instruction and learning, increase of diversity with respect to underrepresented groups, ethical awareness and sensitivity to society impacts, professional and personal satisfaction with the value of having studied engineering, increasing retention rates, flexible programs that foster connectivity across programs and institutions, and reduction in costs [2].

Undergraduate student participants in this study reflected in their answers all of the ideas proposed in the literature, as they too mentioned knowledge and skills as integral parts of what is considered to be excellence in engineering education. However, the participants pointed out some ideas not reflected in the literature, including for example, the quality of the people/educational community, and the desire for more personalized instruction by decreasing student teacher ratios.

In 1990 the Engineering Coalition of Schools for Excellence in Education and Leadership (ECSEL) was established with the purpose of renewing undergraduate engineering education and its infrastructure [11]. This coalition was interested in diversity, the

Study Participants— Excellence in Engineering Education		Fromm [4]—faculty perspective on student characteristics	CASEE [2]—goals to achieve excellence in engineering education
• accredited • accurate • analytical • applied • hands-on • challenging • changing • clear • commitment • **communication** • competitive • complex • comprehensive • constructive • **cost** • current • demanding • detailed • different • diverse • **efficient** • **ethical** • hard work • hybrid • important • informative • innovative • integrative • interactive • international • intuitive • involved • leadership	• **mathematics** • meaningful • modern • multidimensional • **multidisciplinary** • new • personalized • practical • precise • preparing for the future and long lasting • pressure • working towards prevention and safety • quality • reliable • reputable • involved in research • rewarding • robust • **satisfaction** • **science** • selective • simple • specialized • stimulating • technical • understandable • unique • useful • varied • well rounded	• advance knowledge of selected professional-level technologies • a historical and societal perspective of the impact of technology • a sense of corporate and business basics • capacity to apply these fundamentals to a variety of problems • **creative** • culture for life-long learning • **enthusiasm** for learning • intellectual spirit • knowledge and experience in experimental methods • knowledge and skills in the fundamentals of engineering practice • social, **ethical**, political and human responsibility • strong foundation in basic **sciences**, **mathematics** and engineering fundamentals • strong oral and written **communication** skills • unifying and **interdisciplinary** broad view	• convergence with other relevant non-engineering disciplines (**multidisciplinary**) • course integration within programs • depth-of-knowledge • **diversity** • effective instruction • **efficient** instruction • engaged instruction • **ethical** awareness • flexible connectivity across programs and institutions • professional discernment • provides professional and personal **satisfaction** • reduced attrition • reduction in **costs** • sensitivity to society impacts **The Millennium Project [5]—characteristics of education** • adaptive • **affordable** • asynchronous • collaborative • **diverse** • intelligent • **interactive** • learner centered • provides for lifelong learning • a seamless web • ubiquitous

Table 3. Different perspectives on excellence in engineering education.

curriculum, and informal education, but did not consider the learning community, materials, and technology which are some of the aspects that the participants of this study mentioned as relevant. The ABET criteria for accrediting engineering programs is one of the documents that most of the universities around the country use as their standard. This criteria includes a measure to assure *quality of engineering education*; stating that that the *quality and performance of students* is an important consideration in the evaluation of an engineering program. The criteria also state that the institutional *support and financial resources* needs to be adequate to assure the quality and continuity in the engineering program [1]. Overall, the criteria do not explicitly list the technology, the community, and the "quality" of instructors as important factors in engineering education. Many requirements and descriptors are used to define the desired characteristics of instructors, but the word quality is not mentioned in the criteria to refer to instructors or professors.

Among three of the four individual questions, the word that had the most occurrence was "students;" and in the educational technology question it was the seventh most repeated word. From the human factors standpoint of honoring the user, it is a loud and clear message from the user population, or the participants in this study, that they are very important by constantly repeating the word "students." This point is evident in student centered teaching/learning approaches [12].

In the National Survey of Student Engagement (NSSE) 2000 report [13], it was mentioned that students learned more when they are intensely involved in their education and have the opportunity to think about and apply what they are learning. The participants in the focus group considered that part of the their roles as students was to be to be a critic, to ask questions in class or contribute to class discussions, give class presentations; teamwork, work with classmates in and outside of class; mentor, tutor or teach other students, extracurricular activities, participating in community-based projects, participating in research projects, and be exposed to diversity. In general, the more contact students have with their teachers the better; however, the NSSE report mentions that this does not occur very often, which is supported by our results. When students collaborate with other students to solve problems or master difficult material, they acquire valuable skills that prepare them to deal with the problems they might encounter after college.

With the changing nature of the need for higher education, Duderstadt [10] proposes that "both young, digital-media savvy students and adult learners will likely demand a major shift in educational methods, away from passive classroom courses packaged into well-defined programs and toward interactive, collaborative learning experiences, provided when and where the student needs the knowledge and skills…as the student is evolving into an active learner and eventually a demanding consumer of educational services." The data collected in this study echo both the message on the role of new teaching techniques and approaches, and at the same time it shows that many traditional methods such as using a board to present a dynamic and interactive teaching session are most effective. Research has shown that interface design is an important issue in effective instructional technology and methods [14, 15].

B. Focus Group Discussion

1) Interaction between students and professors: When describing interactions between students and professors, many participants mentioned graduate student instructors first rather than professors. Many participants expressed that they had limited interactions with professors, and they hesitated to ask questions and had interactions only if professors were approachable. Figure 1 shows a visual representation of the interactions derived from this research study between the reported roles of professors and students. These interactions shown in the figure (represented by arrows) are based on the results from the individual brainstorming questions about student roles and professor roles, and the results from the group discussion on the interactions between students and professors. Solid arrows represent reported interactions that work between students and professors; connections that are direct and solid. However, the connection between the students and professors, represented by dashed lines, is severed and fragmented by many factors. These factors were

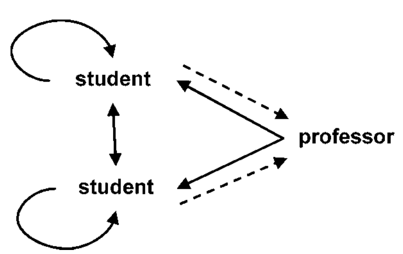

Figure 1. Participant's view of professor's and student's roles.

implicitly described by the participants in this study by describing the environment (e.g. class size and class dynamics), professors' personality, and technology (e.g. e-mails).

In a report by the NSSE [13], five benchmarks were created to indicate the state of student engagement at different types of institutions and by different types of students during the spring of 2000. These benchmarks were created for different questions on 100-point scales by summing all student responses to the question and multiplying the summed responses so that 0 is the lowest score and 100 the highest. One of the questions included in the survey measured student interactions with faculty members and the differences between first-year students and senior students. The school where the seniors have the most contact with their teachers scored 59.4 and the lowest scoring school scored 23.1. For the first-year students, the lowest scoring school was 21.4 and the highest was 45.1, with 50 percent of the scores falling between 30 and 40 respectively. In this same research they found that at public doctorate-granting universities, 53 percent of first-year students and 35 percent of seniors "never" discussed ideas from their readings or classes with a faculty member outside the classroom, and 79 percent of first-year students and 63 percent of seniors never worked with a faculty member in a venue other than classes (e.g., committees). This research shows quantitative data on the issue of interactions between students and professors supporting the results found in our study (see connections in Figure 1), which suggest that interactions between students and professors are very limited. In the future, more data should be collected to understand the reasons behind the limited interaction between students and professors.

There is a substantial body of research on effective teaching which documents the importance of student-faculty contact. Most of this research has focused on student ratings of classroom teaching [16]. They describe good teachers as approachable and interested in students, easy to talk to, and inviting of student views and discussion. Teacher-student contact characterizes good teaching and helps students attain a number of educational goals. In a recent study by Bjorklund, et al. [17] on the effects of faculty interaction and feedback and gains in students' skills, the results show that faculty interacting with and providing constructive feedback to students were significantly and positively correlated to students' self-reported gains in several design and professional skills. This study is relevant because, as mentioned before, one of the main goals of engineering education is to make students develop skills and knowledge. This study suggests the interaction between students and faculty is one of the important factors that affect learning. Chickering and Ehrman [18] also stress the importance of interaction between student and professors suggesting "frequent student-faculty contact in and out of class is a most important factor in student motivation and involvement…knowing a few faculty members well enhances students' intellectual commitment and encourages them to think about their own values and plans."

2) Methods used to present information in the classroom: One clear message from the study participants was that the use of the board or writing on overhead transparencies in the classroom was preferred over PowerPoint presentations, since using the board showed the progression of ideas and gave the professor an opportunity to write down all the steps in the classroom, showing the process. Participants agreed that effective instructors show clear objectives, a balance between concrete and abstract information, and recapitulation or summary of the information presented either during the current lecture class or the material from the previous lecture. This is consistent with Felder et al.'s [19] statement that instructors need to establish relevance of course material and teach inductively by relating the material introduced in class to things students already know.

3) Goals of teaching engineering, and the types of skills and attitudes that need to be learned: The participants mentioned that one of the goals of teaching engineering is developing several skills. The skills they considered most important were critical thinking, problem solving, creativity, organization, and teamwork. They also mentioned communication, discipline, responsibility, interpersonal relations, time management, and writing skills.

A content analysis of Felder et al. [19] shows that the authors mentioned that acquiring a basic knowledge, skills, and attitudes are part of the goals that should be achieved in engineering education. The main skills mentioned by the authors were engineering problem-solving skills (n = 6); creative thinking (n = 5); teamwork (n = 10); written and oral communication skills (n = 7); social awareness (n = 3); and critical thinking (n = 6) which are all in accordance with the skills mentioned by the participants in our study. Whitmire [22] considers that the development of critical thinking skills plays a significant part of undergraduate education. In Whitmire's study, students' perception of gains in critical thinking were mainly dependant of their perceived college environment, the student background characteristics, and the frequency of library activities.

In order to attain the skills needed, students should be given practice and not just passively listen to what they are supposed to do, because people acquire skills most effectively through practice and feedback. Instructors should serve as coaches, providing constructive feedback and encouraging reflection (recaps) to help students achieve the target attitudes and skills [23]. According to Woods et al. [23], the target skills are: communication skills, teamwork (n = 2); management skills (n = 5); self-assessment (n = 5); problem-solving; and writing skills.

Fromm [4] also mentions in his article that students must possess: a basic knowledge, capacity to apply, communication skills (n = 2), management skills, social and ethical responsibilities, interdisciplinary view, critical judgment skills and enthusiasm for learning, teamwork, and interpersonal relations.

The study presented by Bjorklund, et al. [17] examines the faculty teaching practices that are positively related to gains in several design and professional skills, such as problem solving skills (n = 4); teamwork (n = 3); application in the real-world; communication skills (n = 4); and management skills. The study mentions the following as effective methods: working in small groups, hands-on projects, student-student and student-faculty collaborations, presentations, writing reports, providing feedback and academic advice.

4) Teaching methods that work in the classroom: The teaching methods that participants considered to be most effective were the presentation of: examples/applications in the classroom, clear objectives, information in both concrete and abstract ways, and recapping information. Students also valued when the professors were organized and ask for questions at the beginning of a lecture. The study participants mentioned the following as interactive methods: working in groups, in-class demonstrations, experiments, using internet, and any type of activity that is hands-on. They also appreciated when the instructor acknowledged that things were difficult and helped the students simplify the material by providing handouts and giving "time to soak." These comments are consistent with what were proposed in Felder, et al. [19–21] who suggested doing recaps, using real world applications, giving clear objectives, working in teams, providing handouts or a course pack, and using the Internet, as teaching methods that work in the classroom.

5) Perspectives on course evaluations: Course evaluations are considered to be one of the important measures of teacher success and course satisfaction. Participants suggested that the evaluations need to not only be a general course evaluation, but to approach teaching and methods used. In general, participants perceived evaluations to be standard and not asking questions that are relevant to the course they were taking. There was consensus among the participants about the personalized questions in the course evaluations. Students shared that asking open-ended questions in the evaluations was valuable for them as well as directly approaching students for feedback.

V. Conclusions

When it comes to excellence in engineering education, the general feeling is that students would like to see more opportunities to give input to the system. Much can be learned from involving students in the process of educational/instructional development. It is very important to recall that students repeatedly emphasized that they are an important part of the system.

The word "example" was the one word that seemed to be most important to the participants of this study other than the word "students." In the question about educational technology, the word "example" came up in the context of creating technology that is interactive and provides real-life examples, and technology that allows teachers to illustrate examples. In the question on "excellence in engineering education" participants mentioned that excellence is associated with real life examples and providing more examples. For this question, the word "example or real life examples" was written by 32 percent of participants, and was also ranked by 71 percent of them as one of the top five priorities in comparison to the other ideas mentioned about excellence. During the focus group discussion, the word "examples" was mentioned by participants in four of the ten questions that were discussed. The results from this study show that it is important for students to see and work with examples in their engineering courses.

Research literature on excellence in engineering education stresses the importance of skills and knowledge, but leaves out the technology component and the building of relationships that seem to be important to the participants of this study. "Technology" was written by 16 of 47 participants in this study (34 percent) as one of the things that came to mind when they thought about excellence in engineering education.

This study provides concrete evidence that we need to attract not only policy makers, educational researchers, teachers, and industry, but that we need to get the students involved in the creative process so they can participate more in shaping their learning environment and creating a community of excellence. The study shows that the views of the students often overlap with, but are not always identical to, those of the educators. Further study of this issue with a larger sample of students with diverse backgrounds and characteristics would give us more insights into the definition, perception, and achievement of excellence in engineering education.

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