# Ethnography of a First-Year Design Experience in the Introduction to Engineering Design Course

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*Abstract* - **The *How People Learn* (HPL) framework was used to re-design Introduction to Engineering Design, which is a first-semester required course for every engineering program at *Universidad de las Américas Puebla*. The VaNTH Observation System was used to systematically assess HPL framework implementation in the classroom. Conducting an ethnographic study is an exercise in making visible experiences that get hidden. In this case, our task was to make visible patterns in first-year student experiences with the dominant model of engineering problem solving. Conducting intensive ethnographic research for two semesters at Introduction to Engineering Design classrooms, our team produced 500 pages of transcribed and coded data drawn from bi-weekly interviews with focus groups, individual interviews, and assorted assignments, journals, projects, quizzes, presentations and lectures. VaNTH Observation System captured differences in EI-100 classroom experiences, which may be used to measure levels of "HPLness" of a lesson. The ethnographic study explored how first-year engineering students interpreted design assignments in terms of the engineering sciences. These first-year students, who had been taught to value the distinction between "science" and "design", tended to resist the engineering design approach to problem solving. Although limited in scope, our study suggests that for the first-year design experience to be successful, we may need to redesign the course.**

*Index Terms* - Engineering design, Ethnographic study, First year courses, How People Learn.

## BACKGROUND

*Universidad de las Américas Puebla* (UDLAP) is a Mexican private institution of higher learning committed to first-class teaching, public service, research and learning in a wide range of academic disciplines including business administration, the physical and social sciences, engineering, humanities, and the arts. The studied course, Introduction to Engineering Design (EI-100) is a first-semester 3 credit required course for almost every engineering program of UDLAP since spring of 2001. Course content and classroom activities are divided into three, two-hour sessions (Modeling, Concepts, and Laboratory) per week. Students have six different EI-100 facilitators (an instructor and teaching assistant for each session). EI-100 goal is to introduce students to the Engineering Method, this is accomplished by focusing on six course objectives: self-regulation, communication, working cooperatively and collaboratively, problem solving, modeling, and quality. The "Modeling" session initiates students in the process of engineering modeling, using several software including spreadsheets. "Concepts" introduce students to the engineering design process, problem-solving techniques, working in teams, engineering as a profession, and planning for success that students then apply in "Laboratory" on two actual design projects.

UDLAP's Chemical, Civil, Computer, Electrical, Environmental, Food, Industrial, Mechanical, and Mechatronic engineering students have in EI-100 a great opportunity for a multidisciplinary collaborative experience. EI-100 is a team-taught course that uses active, collaborative and cooperative learning, which has been a major player in UDLAP's efforts of engineering education reform [1]. However, EI-100 could be improved taking into account technological advances and recent research on human learning and cognitive processes that underlie expert performances. Re-designing the course EI-100 we could improve student understanding of the engineering method, and student ability to solve practical engineering problems and complete real-world engineering projects while increasing active student participation, peer-team interactions, and feedback processes.

The *How People Learn* (HPL) framework was used to re-design EI-100 [1]. HPL framework highlights a set of four overlapping lenses that can be used to analyze any learning situation. In particular, it suggests that we ask about the degree to which learning environments are knowledge, learner, community, and assessment centered [2]. The VaNTH Observation System (VOS) is an assessment tool developed to capture qualitative and quantitative classroom observation data from teaching and learning experiences. VOS is a system that incorporates the elements of HPL framework and uses 4 recurring methods of collecting classroom data: recording student-teacher interactions (CIO), recording student academic engagement (SEO), recording narrative notes of classroom events (NN), and rating specific indicators of effective teaching (GR) [3, 4]. To make more visible the first-year student design experience, we conducted an ethnographic study [5] in addition to VOS ethnographic components [3].

## METHODS

VOS was used to systematically assess HPL framework implementation in EI-100 classrooms [1]. Over the course of the past year, three observers trained in VOS sat in EI-100 classrooms and observed 9 professors, both junior and senior level, in over 60 class sessions from the three different EI-100 sections. Classes ranged in size from 30 to 70-plus. Observers conducted a minimum of six observations per class. Observation dates were randomly selected throughout the semester. Conducting an ethnographic study is an exercise in making visible experiences that get hidden [5]. In this case, our task was to make visible patterns in first-year student experiences with the dominant model of engineering problem solving. We do not in this work attempt to make visible ways in which engineering faculty enhance, resist, trouble, or otherwise struggle with the dominant model. Conducting intensive ethnographic research for two semesters at EI-100 classroom, our team produced 500 pages of transcribed and coded data drawn from bi-weekly interviews with focus groups, individual interviews, and assorted assignments, journals, projects, quizzes, presentations and lectures. The goal was to gain a clear understanding of what was happening in EI-100, seeking to get to know the course culture from the points of view of many of its stakeholders.

The population for this study was everyone of the students who took the course in 2008: approximately 160 students, 9 professors, and 9 TAs; several professors who in the following semester received students who passed EI-100, and a sample of engineers that work at various firms in the area and who are employers of graduates from UDLAP engineering school. The unit of analysis included the three sections of EI-100 offered during 2008. Using VOS, a total of 252 observations were generated in each of the two groups (504 in all) during the semester, based on six observations per class and three days of class per week for 14 weeks. The independent domain variables were: implementation of the HPL framework, introduction of Tablet PC technologies as instruction tools, the general structure of the course (three different sessions per week with different professors and grading systems), and course content. The dependent domain variables were: the development of engineering abilities in first semester students, acquisition of specific engineering design knowledge, improved grades, and increased motivation.

Once the different domains were established, a data collection plan was drawn up. The data considered for this study may be classified as follows:

- Data collected through VOS
- Data collected through participatory observation and informal interviews with students on site (more than 250 hours). Observation was carried out in two stages: first, familiarization with the context, students, professors, TAs, course content, classroom, activities; and second, a selective observation stage in which, according to the designed model, we sought to identify the level of HPL implementation at the three sessions, the impact generated in the students and professors by the use of HPL framework and Tablet PCs in the classroom, student's level of achievement of the target competencies, impact generated in students by taking a course (in their first semester) with a structure totally different from the "traditional" instructional model they are familiar.
- Course exit surveys
- Interviews of students who took EI-100 and are now in third or fifth semester.
- Interviews with engineers who are employers of graduates from UDLAP engineering school.
- Analysis of secondary materials: grades and course evaluations from 2001 to 2008.

## RESULTS AND DISCUSSION

### *I. VaNTH Observation System (VOS)*

Based on results from VOS three instruments (CIO, NN and GR), it may be concluded that the EI-100 is aligned with the HPL framework [1]. VOS allowed us to discern important differences between sessions and professors (Fig. 1). What stood out was that the sessions with the highest percentages of HPL-oriented activities were those taught by facilitators who had more experience with the course and especially with the HPL framework [1].

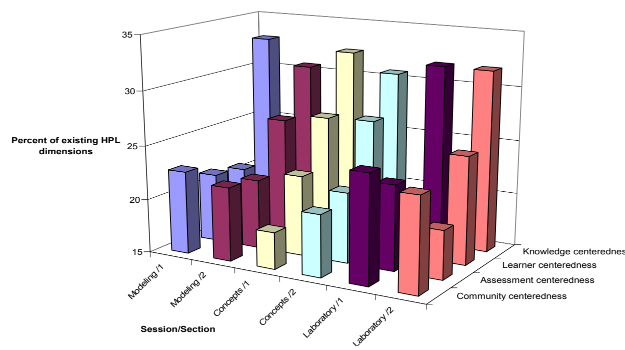


FIGURE 1
PERCENT OF EXISTING *HOW PEOPLE LEARN* DIMENSIONS IN THE COURSE INTRODUCTION TO ENGINEERING DESIGN SESSIONS (MODELING, CONCEPTS, AND LABORATORY) IN FALL 2008 SECTIONS 1 AND 2.

### *II. Comments from direct classroom observation and informal talks with students from the course.*

Participative observation was performed in two stages: familiarization and selective observation. During the first stage, it was observed that the students are first-year engineering students at the UDLAP and mostly men. Students come from different states in Mexico, mainly from the southeast states and the city of Puebla.

An average of 33% students enrolled in EI-100 for Fall 2008 have some kind of scholarship to study at UDLAP (between 2001 and 2006 about 49% of students had an scholarship). Further, their level of mastery of English is low and their mastery of computer applications such as Excel is fair. Data show that historically, first-year university students had entered with a higher level in English and computing in previous years.

Each class session lasted two hours, including a ten-minute recess; during the first weeks of the course, the students were punctual at the beginning of class and at recess. As the course went on, students' punctuality diminished, especially for Friday Laboratory sessions.

The course is taught in a large classroom with 20 tables with four students each; each table has a desktop computer. The classroom has six boards, two projectors and two screens. There is also a total of 20 Tablet PCs, one for each four-student team. The instructor's Tablet PCs is wireless connected to the projectors, so instructors are able to move within the classroom with his/her computer. The classroom is equipped with a sound system with a tie clip microphone for the instructor and two microphones for the students.

EI-100 is student-centered and takes into account students' prior knowledge as well as their learning styles; this is done by asking all the students to complete two surveys at the beginning of the semester, the first about their knowledge of English language and their mastery of Excel, as well as several demographic data; the second one, is the Index of Learning Styles survey [6]. These data is used by professors to organize teams and to design learning environments throughout the course. Several active, collaborative, and cooperative learning techniques are employed with the intent of improving communication and student learning. During the course of the semester, the importance given to formative assessment was observed: professors regularly assess at the beginning, during and at the end of the class, fostering activities in which students give evidence of their thought processes. Professors use these opportunities to correct errors and reorient learning. In fact, the use of Tablet PC technologies in the classroom has greatly enhanced assessment processes in EI-100. Using Tablet PCs, self- and team peer-evaluation are frequently performed, improving student learning by offering more opportune feedback. Formative assessment is also achieved by giving the opportunity for students to improve their work products that had not received a "meets expectations" grade.

EI-100 is also student-centered since it promotes metacognition, reflection and auto-regulation. Further professors display excellent instructional audiovisual tools in most of class sessions. Another aspect observed in EI-100 and which leads us to conclude that the course is knowledge- and student-centered, is the excellent time management by the instructors, above all in the Concepts and Laboratory sessions. Every class session begins by explaining the objectives, competencies to be achieved, and the agenda for the two-hour session, including the recess. Professors do their best to respect times for each of the activities and always set aside time for "burning questions", that is, for students' questions that can't wait to be answered. The class session always ends by showing a brief agenda of the next session, as well as the tasks and activities to be performed prior to the next class. It should not be forgotten that in many classes students are asked, before leaving the classroom, to leave a Post-it with a positive comment for the session and one on some aspect that could be improved.

Cooperative work performed throughout the semester is very important. In fact, it could be said that the entire course is planned to be community-centered. Students organized in teams work with the same group in the three sessions during the entire semester, becoming by the end of the semester, in several cases, high-performance teams. In order for the students to familiarize themselves with the work that engineers do every day and with the abilities they need to develop in order to be considered strong candidates for jobs, UDLAP alumni engineers are invited to come to class. These engineers hold different, important positions in the community, and they share their experiences with EI-100 students. These visitors tell the students that companies not only hire engineers for the knowledge they possess, but also for their abilities and competencies, which they develop throughout their professional career. According to the informal interviews, these activities are very popular with the students, and they always ask for more visitors.

Direct observation and informal interviews allowed us to learn about the change students experience throughout the semester. The impact the students feel from a course with a learning scheme so different from the "traditional" one they have always encountered, is very important. They are at university for the first time, beginning their course of study, many of them have changed their place of residence, and they are living outside their parents' homes for the first time, on their own, or in UDLAP dormitories.

Students say that their first impression of the course on them is the large classroom, with so many classmates (around 80) and such a different distribution from the one they are accustomed to. After the initial impact, there are others: having classmates from different engineering programs, being enrolled in one course that from their point of view is really three courses: Modeling, Concepts and Laboratory, each one with a different professor and grading scheme, and especially taking a class in which a very important aspect are the competencies to be developed.

Another aspect that surprises students is the assessment and evaluation scheme for the course. They say that taking a course in which there are so many aspects counting towards their grade confuses them at the beginning of the semester and that they need several weeks to adapt to the system and realize that it is a system from which they can benefit more than the one utilized in other subjects. Many students said they did not like receiving the same grade from a work product as their entire team when not every member contributed equally.

An important learning goal of EI-100 is to enhance students written and oral communication skills therefore multiple opportunities were given to the students to practice, receive feedback and enhance their written work-products and oral presentations. One of the skills we want students to develop over the semester is the ability to critically evaluate their own and others' work. In order to do this, students self-assessed most of their work while in "Laboratory" almost every week they peer-assessed other teams' work. This is a skill we think is very important to develop as future engineers so we take the peer assessment process seriously. For this to be an effective process, students must learn how to give and to take constructive feedback.

According to the student interviews performed over the course of the year, creating the two Laboratory projects is what motivates them most in the course. Students say it is really motivating that they be allowed to create and dissect objects and prepare instruction booklets, and that there is no better way to learn something than by designing "something" which solves a real problem. The students have requested a greater number of these types of projects and activities in the course.

*III. Student surveys.*

Over the years that EI-100 has been offered (2001 to 2008), an exit survey has been applied to students at the end of the course. The students must answer four questions: how hard was the course? How was the workload in comparison to other same semester courses? Was the course pace appropriate? And what could be improved in the course?

For the question how hard was the course, a very high percentage of the students in every semester (from 2001 to 2008) said the course is not difficult, but the tough part was taking a course with a system so different from the one they have been accustomed to. The difficulty lies in adapting to teamwork since it is not easy to effectively communicate and work in teams. Students say that for the first time they had to be responsible, organized and constant, and that this has also been a change and a difficulty in their lives as students.

In response to the question how was the workload in comparison to other courses? Students said the course has a very heavy workload; in fact, greater than any other course they take that semester. They say they have had to work in the course, arrive in class having read and studied, having done their homework and having had to meet with their team. They also say it is a process of adjusting, and as the semester goes on they get accustomed to the structure and rhythm of the work, they get better organized and have less trouble meeting the expectations.

Most students answered "yes" to the question: is the pace of the course appropriate? Some students said they would like to have more time in the Laboratory sessions and less for Concepts, because they generally find Laboratory to be more motivating, but they admit to needing the theory they get in Concepts sessions.

The suggestions students gave for improving the course were numerous and varied. Some of the suggestions involved improving the course assessment and evaluation system, doing more projects, making visits to industries and companies related to their engineering major and increasing the number of visiting engineers, to name a few.

*IV. Summary of interviews with a sample of engineers.*

According to the sample of engineers surveyed, the most important abilities (from Criterion 3 program outcomes of the Accreditation Board for Engineering and Technology, ABET) that students need in order to work at their companies are to function effectively in multidisciplinary teams and communicate effectively, the ability to design and implement experiments as well as to analyze and interpret data and recognize the need to become involved in a lifelong continuous learning process.

*V. Summary of interviews with former students of the course.*

EI-100 seeks to start developing a series of competencies in engineering students, competencies which coincide with ABET's Criterion 3 program outcomes and will be further developed during their entire program of study at the university. A survey was designed using a Likert scale with values from 1 to 5 (1 being none and 5 a lot), and it was applied to students who had taken the EI-100 course, in order to determine the level of importance they gave to each of the competencies (outcomes); the same scale was employed to measure the level of progress the students felt they had reached in each of the same competencies after the course.

Competencies with the greatest importance for students are the ability to identify, formulate and solve engineering problems, the ability to work in multidisciplinary teams, and the ability to analyze and interpret data. In terms of the level of progress students feel they have reached after having taken the course, the competencies of greatest progress are the ability to work in multidisciplinary teams, the ability to organize and present oral and written reports, and the ability to identify, formulate and solve engineering problems. Thus, what stands out is that the students who have completed EI-100 perceive that collaborative work in multidisciplinary teams is an ability that is important to develop for their career and in which they achieved important progress. The same occurs with the ability to solve problems.

*VI. Analysis of printed materials*

An analysis of several printed materials was performed. In contrast to the observations and interviews which have been detailed previously, for the analysis of the printed materials we decided to carry out an analysis of what has occurred in EI-100 between 2001 and 2008. For this paper, we decided to only include two analyses: student grades and student answers to the exit course survey.

Figure 2 presents EI-100 final grades obtained by students from 2001 to 2008. It is important to mention that at UDLAP the minimum passing grade is 75, which is important to this analysis since it can be observed that the student final grades in EI-100 have been very good. The best year was 2003. In most years, higher grades are observed in the spring than in the fall semester. It is worth mentioning that beginning in 2006 the average final grades began to drop, and that this decrease has continued until 2008. This may be explained by the fact that starting in Fall 2006 the course ceased to be offered to second-year engineering students, becoming a first-semester required course. This, combined with the fact that students are entering with continuously lower levels in English and the use of computer applications such as Excel, may be causing the observed decrease.

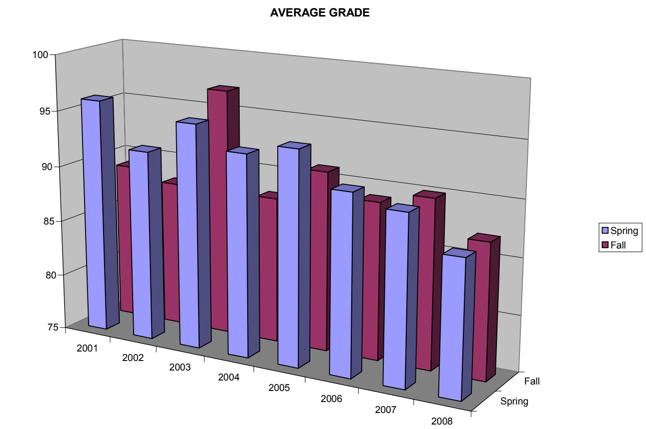


FIGURE 2
INTRODUCTION TO ENGINEERING DESIGN FINAL GRADES.

Figure 3 exhibits the percentage of students who failed the EI-100 course from 2001 to 2008. The first three years, in which the course was offered, the percentage of students failing was very low. The fall 2004 semester had a very high percentage of students failing the course (or dropping it). High percentages of students failing were observed in 2006 and 2007 when most of the students enrolled in the course were first-year students. In the US, an estimated 20% of the entering students are not ready to study engineering [7]; the overwhelming weakness reported is mathematics. However, the re-designed (2008) EI-100 course significantly ($p<0.05$) decreased the number of failing students.

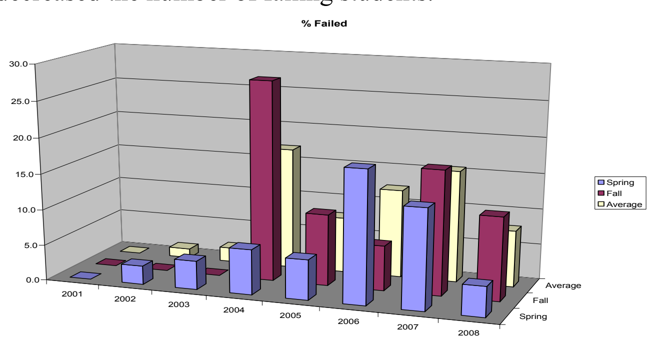


FIGURE 3
PERCENTAGE OF STUDENTS THAT FAILED THE COURSE.

At the end of the course, students fill out an exit survey, which serves as a feedback tool for the professors and course designers in order to correct and improve the course and reorient teaching and learning activities, thus making it possible to offer a revised and improved EI-100 course for the following semester. The survey is closely linked to the competencies which the course seeks to develop and which have been discussed previously. The instrument is made up of 20 questions (Likert scale with assigned values from 1 totally disagree to 4 totally agree) classified in six categories, as follows:

Active, Collaborative, and Cooperative Learning

1. I analyze and attempt to solve problems as engineers do. 2. I integrate what I have learned in different sessions. 3. I am interested in the way in which I learn. 4. I learn from my classmates. 5. I put my own ideas into practice. 6. I think independently.

Student Effort

7. I work hard and study for the course. 8. I come prepared to each class. 9. I participate effectively in teamwork.

Course Objectives

10. I understand and apply the modeling process. 11. I organize and present effective oral and written reports.

Communication and Interaction

12. The professors present the topics in a non-traditional manner. 13. The presentations are clear. 14. There is more opportunity to have my questions answered. 15. The professors pay attention to the progress of each student.

Evaluation

16. The quizzes refer to course content. 17. I understand the course assessment and evaluation system.

Methodology

18. The problems, exercises and case studies contribute to learning. 19. Team projects contribute to learning. 20. Use of the computer contributes to my learning.

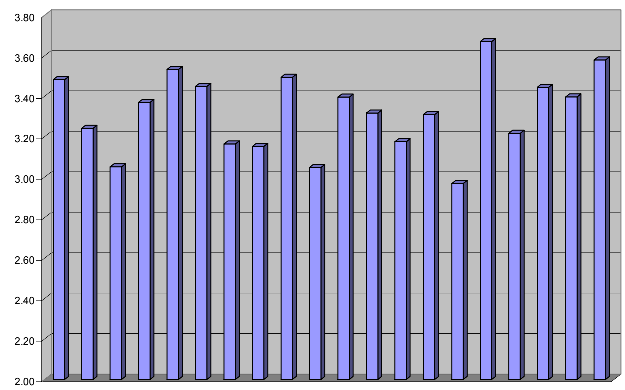


FIGURE 4
INTRODUCTION TO ENGINEERING DESIGN EXIT SURVEY RESULTS (IN ORDER, FROM QUESTION 1 TO 20).

Figure 4 presents exit survey results from 2001 to 2008. Briefly, the highest values were obtained in questions 16, 5, 20, 1, and 9 respectively. As has been mentioned previously, the instrument is closely related to the competencies the course seeks to develop, so the items offer information about the progress students believe they have achieved. Most of the competencies are achieved through active, collaborative, and cooperative learning. In general, students agreed that active, collaborative, and cooperative learning are important elements in his/her formation as engineers. The lowest values were obtained in questions 3, 10, and 15, respectively, revealing areas of opportunity for the course.

Average scores received into each one of the six categories of the exit survey are presented in Figure 5. In general, students agree or totally agree to many of the affirmations included in the 20 questions. In average, communication and interaction, course objectives and student effort received lower scores than active, collaborative, and cooperative learning, evaluation and methodology. There is a significant difference ($p<0.05$) among years, receiving lower scores in years 2006 to 2008.

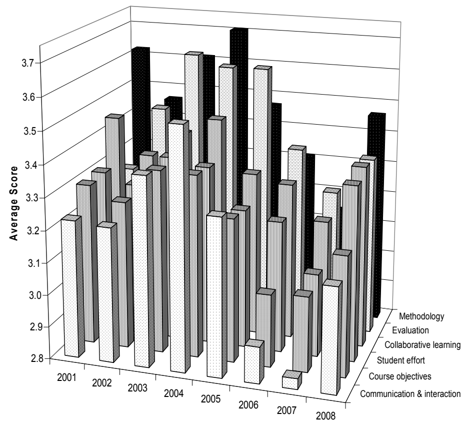


FIGURE 5
INTRODUCTION TO ENGINEERING DESIGN EXIT SURVEY RESULTS BY CATEGORY.

Figure 6 illustrates the average scores received before and after fall 2006 (term in which EI-100 began to be offered in the first year of the curricula). In general, there is lower agreement for survey affirmations after fall 2006, especially for "interest in the form in which I learn", "integrate learning form sessions", and "I learn from my classmates.

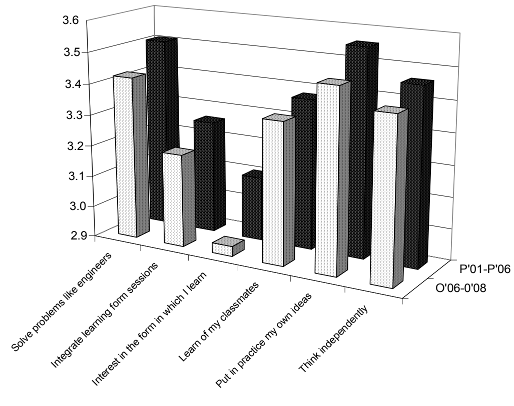


FIGURE 6
INTRODUCTION TO ENGINEERING DESIGN EXIT SURVEY RESULTS.

Still, the ethnographic study explored how first-year engineering students interpreted design assignments in terms of the engineering sciences. These first-year students (spring and fall 2008), who had been taught to value the distinction between "science" and "design", tended to resist the engineering design approach to problem solving. Similar results have been observed (anecdotally) since EI-100 is a first semester, required course.

## FINAL REMARKS

The ethnographic study has made visible patterns in first-year student experiences while allowing us to gain a clear understanding of EI-100 course culture, its stakeholders, and its progress. Although limited in scope, our study suggests that for the first-year design experience to be successful, we may need to redesign the course taking into account that nowadays it is a required first semester course. In the US, first-year engineering courses have extensive professional activities such as socially relevant examples, interpersonal skills, leadership skills, and teamwork; most of the engineering design courses include hands-on projects [7] such as EI-100. In spite of this, Kilgore *et al*. [8] recently found that beginning engineering students, particularly women, are sensitive to important contextual factors. Thus our course re-design efforts to broaden participation in engineering should consider legitimizing and fostering context-oriented approaches to engineering earlier in the curriculum.

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