Invited Contributions to STEM Education NON-REFEREED ARTICLE

Failure Rates in Engineering Service Courses

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Abstract

In this paper, we interpret our findings on the failure rates of engineering students enrolled at San Jose State University (SJSU). A staggering 40% of first year engineering students fail to proceed to the second year, and of those who do, 30% fail in many of the fundamental engineering courses. Although engineering is not meant to be an easy program, the results of students are nevertheless alarming. Many researchers have argued that students fail in these courses because there is a lack of preparedness for the rigorous academic standards required in engineering. While the average college course requires only 2 hours of extra study for every one hour in the classroom, engineering courses require an estimated 4 hours of extra study because of the difficulty levels of the courses. Although the engineering education system works well for the conventional or typical engineering student, the teenagers who enroll in these programs at SJSU, do not necessarily fit this profile. In many cases, these students attend classes and also have jobs or family or both. The education system is not built to cater to the needs of such students, and the results are usually negative. This paper presents initial results of a research project on the failure rates in engineering at SJSU, where 40% of engineering students work more than 10 hours per week while going to school full time. We focused on 3 fundamental engineering courses: mechanics of materials, dynamics, and introduction to circuit. This pilot research project addresses the question *"What do failure rates in these fundamental engineering courses really measure?"*

Introduction

Engineering has great impacted our lives, both as a discipline and as a profession. The quality of human life is affected by engineering design and development. The products made through engineering have made life better for humanity, thus the training and education of engineering students are extremely important. Due to the dynamic nature of engineering, the education of these students should include strong emphasis on fundamental concepts as well as establishing a desire for life-long learning[28] in students. Most engineering educators would agree that educating future engineers with a strong focus on fundamental concepts is no trivial goal; and the task becomes even more important when students are taught in large lectures[31,59].

Due to budget constraints and the need for cost reduction, numerous commuter schools including San Jose State University (SJSU), have chosen the route of teaching fundamental classes in large lectures[10,42,27,54]. The debates around the effectiveness of large lectures can be primarily interpreted in two ways. Christopher's[12] study found the following:

1. The proponents of large lectures argue that large lectures bring a large number of students, and this provides other faculty the opportunity to teach special topics, undergraduate and graduate, that might not otherwise be offered due to budget and other resource constraints.
2. The opponents of large lectures argue that large lectures dilute the learning process, place an undue burden on faculty in terms of test monitoring, grading, office hours or student interaction, and course management.

Whichever direction one favors, whether attempts to move toward smaller lectures or larger ones, or one believes more in one idea over the other, there is a perspective that has been long neglected –the perspective or opinion of the students. The central issue is not small versus large lectures, but the effectiveness of student learning.

The facts demonstrate that in fundamental engineering courses, such as, in mechanics of materials, dynamics, and introduction to circuit, where a lecture could fit upwards of 40 to 400 undergraduates or more, a totally different level of difficulties is experienced. Faculty who teach these courses to a large number of undergraduates will probably list a significant number of similar types of difficulties; among them are: organization of administrative work or paperwork, the management of distractions, anonymity of students, absence of adaptability to class activities, and diverse background and preparation levels for students[10,27,36]. In a similar manner, a few issues emerge when students are enrolled in courses with several others in large groups; among them are: immediate impersonal environment, minimal contact with faculty, getting "lost in the crowd", low motivation and insignificant contribution, and shallowness of understanding[42,85]. Regardless of whether a faculty or a student participates in a large lecture, various studies[2,17,21,27,75] have demonstrated, over decades, that the nature of instruction in a large lecture class is not identical to that in smaller classes. In fact, smaller classes can be more effective.

Problem Statement

The National Institute of Education stated in a report in 1984 that active involvement of students is necessary in the learning process, as stated in the report Involvement in Learning: Realizing the Potential of American Higher Education[73]. Since then, many learning theorists, faculty development consultants, and researchers in higher education have recommended the importance of interactive and participatory student learning that affect cognitive and intellectual growth in students –and several articles and research papers have been published on this topic since the release of the report. Yet, despite these recommendations for interactive and participatory student learning, college and university professors continue to use the lecture method –and in some cases, they conduct classes in large lecture halls with hundreds of students[36]. Part of this is due to the lure of economies of scale, which refers to the cost advantages that an enterprise, in this case, a school, obtains due to expansion[54]. The large lecture format is still dominant in many universities because it is economical and has become the quick and convenient cost-cutting strategy[42]. "Large classes are very prevalent in many universities and are often gateway courses to students' major fields of study"[70]. In engineering, the introductory fundamental courses such as mechanics of materials, dynamics, and introduction to circuit use this sort of practice with "herding" or gathering of students in large classes. This practice poses a difficult situation for freshman and sophomore college students, who may struggle to understand basic concepts and yet have little opportunity to interact or ask questions in large lecture settings. Cooper and Robinson14 expressed the potentially dangerous consequences of subjecting freshman and sophomore college students to large lecture classes with the following statement:

> A growing body of research, points to the value of undergraduate learning environments that set high

expectations, promote active and interactive learning, and give students personal validation and frequent feedback on their work. These settings and practices are especially beneficial for beginning learners as they make the transition to college. Yet in most universities, introductory courses that fulfill their curriculum requirements often carry enrollment of hundreds of students. These large-class settings have historically been heavy lecture-centered, requiring minimal student engagement and expecting little more than memorization of terms and concepts as evidence of student learning. The sheer size and anonymity of large classes seem to weigh against the very elements that promote students' involvement and intellectual development, learning, and success. Inattention or absence from class and mediocre student performance seem to be tolerated simply as unfortunate realities[14].

The three large fundamental engineering courses considered in this study pose a different set of issues or challenges, implying that quality teaching is not possible in large classes. Some researchers in education[10,42,54,75] suggested that quality teaching is quite possible in large classes while focusing on student-centered, cooperative, active experimentation, high-level thinking and learning, instead of the traditional teacher-centered, individual, reflective observation, and large lecture based routine-drill or rote learning.

Felder[23] recommended the need to change the methods of instruction in engineering classrooms. Many engineering classes in 1999 were taught in the same way as classes were taught in 1959 and the existing teaching and learning strategies in engineering have been considered outdated and needed to become more modern and student-centered[23]. In the 21st century, the paradigm or methodology of engineering education is still essentially the same in the college of engineering at SJSU, as studied here, and the need to identify an effective and affordable teaching approach applicable for large fundamental engineering courses, still exists and is in fact paramount importance to improve educational standards. Several researchers[31,45,52] echoed Felder and suggested that the overall aim of a new paradigm is that students must learn and apply a systems approach to engineering problem-solving, such that when they become practicing engineers, they can easily develop sustainable solutions to problems.

The Purpose Of The Study

The purpose for this study is to compare the process of designing an educational plan, especially courses taught in community colleges versus those taught at SJSU –the focus is on 3 fundamental engineering courses at SJSU: mechanics of materials, dynamics, and introduction to circuit. All these courses have been customarily taught in large lectures, and the principal instruction basically centers around verbal and printed words, rote memorization, and is typically lecture driven. Students are acquainted with the concepts they should learn, and these ideas are introduced deductively. Faculty conduct lessons by introducing and clarifying ideas with the students, and students are required to practice the concepts. This paper presents preliminary analysis of the study of comparisons of prerequisite courses for the above aforementioned fundamental engineering courses taken in community colleges versus taken at SJSU) is 86.1% (Fall 2014 entering freshmen) and the 6-year graduation rate is 56.1% (Fall 2009 entering first year students). While the 6-year graduation rates at the college of engineering are low for Asian students (62.6%) and White students (59.4%), the 6-year graduation rates for African American (40.4%) and Latino/a (44.2%) students (Fall 2009 entering freshmen) are genuinely unacceptable. SJSU has numerous innovative initiatives and institutional efforts to support student success and inclusive participation; however many of these endeavors center around improving student services and technology/infrastructure instead of focusing more on instructional methods and pedagogies, especially strategies of teaching in large study halls. The following elements will be explored in this investigation in general: financial constraints and socioeconomic diversity of students, health problems, work load versus course load, enthusiasm in learning environments, confidence in pre-engineering courses, and relationships with the instructors. This paper is focused on whether taking prerequisite courses at community colleges is academically more beneficial for the students than taking them at SJSU. The main difference is class size.

Research Questions

The research questions explored in this preliminary analysis of the study are:

1. *What factors contribute to failure rate in mechanics of materials, dynamics, and introduction to circuit courses at SJSU?*
2. *Does taking prerequisite courses at community college versus SJSU influence the outcome of performance in the target courses?*

Significance Of The Study

As a component to improve engineering education, this investigation will fill in as a significant reference on approaches to advance a better understanding of effective instruction procedures and the elements of student learning, particularly in large engineering classes, at the college of engineering in SJSU. It has been recommended that mediation, intervention or reform style teaching improves scholarly accomplishment over conventional lecture based styles1,[59,88]. This study is based on an investigation on large fundamental engineering courses, especially, particularly mechanics of materials, dynamics, and introduction to circuit, in SJSU.

Literature Review

One of the ironies of higher education in the US is that most professors at leading colleges and universities do not have any formal training in education or teaching[3,22]. Most current graduate training programs focus on the development of research and scholarly skills rather than skills related to instruction[18,50]. As a result, few faculty members have any systematic knowledge or experience in preparing and delivering effective lectures, in leading classroom discussions, or in the mentoring of graduate and undergraduate students[8,78].

A second irony is that while Ph.D. programs at educational institutions commonly stress research and other scholastic grants, only a few graduates of these courses finally secure research positions at organizations. Rather, a large number of them go to organizations that emphasize teaching as a primary job and responsibility[35]. One of the results of advanced education, for a considerable number of these students is that the progress from graduate students to faculty member is difficult. Most can transform into a powerful educator on the job[22], putting a lot of their time as a teacher to create courses, structuring and updating talks, and learning answers for the issues that students bring to them in their classes[8] .

The third irony is maybe the most peculiar. Many educational institutions (and the academic departments within them) ask their least experienced faculty (commonly, new assistant professors or lecturers) to teach large courses, particularly in their first few years[8,22]. Usually these courses have many students and are, by size, among the most challenging in terms of educating effectively[13,36,62,48]. However, many senior faculty members see giving these courses as a transitional experience, or a preparation period that all faculty must go through during the early profession stage, paying little attention to their capabilities or skills. The act of "giving" these course is an obligation to be fulfilled by all new junior faculty and that is unfortunate. Usually, junior faculty have the least information and involvement in teaching within a large classroom setting[22,49].

These ironies plus the massive shift which is occurring in higher education, driven by complex forces including financial, administrative, technological and organizational and stakeholder expectations are not only changing the world, but has led to the emergence of educators improving and maintaining the quality of teaching and learning outcomes while contending with increasing class size. Large classes will continue to be the cultural norm in higher education, despite mixed evidence on its effectiveness and student outcomes. However, the culture and practice of teaching large classes also provide the impetus for innovative solutions to overcome the challenges in higher education.

Definition of Large Classes

In spite of the fact that for a long time, analysts have considered the impact of class size on instructional adequacy and student learning, large classes in advanced engineering education is a term that has no acknowledged definition. A few institutions use the expression "large" to allude to classes of more than 40 students[15], while other institutions see a large class as one with more than 200 students62. Generally, a class over 100 students, would be considered as "large".

Challenges and Opportunities of Large Classes

Instructing large classes has its own dynamics and presents critical difficulties to the workforce. Several researchers[13,45,48,52,62] concur that faculty members portray large classes as a more challenging setting for education than smaller classes since they require more stress and greater attention to relationships with the students and the management. Holding students' attention in a large lecture room is more difficult than in a class of 20 students –due to the fact that in a large setting, students are physically distant from the instructor. Many parts of the course should be deliberately sorted out, even scripted, in light of the fact that basic errors in lectures, tasks, or tests may confuse many students. Errors in instructions are additionally challenging to readdress when a large student population is involved. Large classes may likewise require a level of management and supervision[48,52] that can be incredibly tedious. Since numerous educators of large classes depend on graduate students or teaching assistants to lead conversation segments and assess student tests and papers, faculty members should cautiously supervise and help the graduate assistants, in addition to working with the undergraduates.

For students, large classes offer a different set of challenges. Some students feel anonymous[13] in large classes because they rarely know many of the other students (if any) and the faculty member rarely gets to know them as individuals. Students find this anonymity impersonal and off-putting[13], particularly students who are used to a smaller and more supervised learning environment. Unfortunately, the impersonal quality of large classes is sometimes coupled with limited access to instructional assistance. With very large numbers of students, faculty members and teaching assistants have very limited time to devote to any one individual. As a result, students must learn more independently, relying less heavily on interaction with the instructor and more heavily on their own abilities and interactions with teaching assistants and peers[48].

Despite these challenges, large classes may provide faculty members and students with unique opportunities for teaching and learning, and can have several advantages. Given their size, large classes often include a more diverse group of students[14,82]. Diversity enlivens conversations and discussions, and makes for more interesting learning experience. Equally gratifying is the faculty member's sense of wide educational impact in large classes where ideas and materials are studied and learned by many students from very different educational backgrounds and perspectives[9]. Finally, working with teaching assistants in large classes is often quite rewarding. Many faculty members believe that there is little that they do which is more important than training the next generation of faculty members who learn the art of how to teach effectively[48]. Large classes provide a valuable context for this training for the future generation of teachers.

Many undergraduates thrive on large classes for precisely the same reasons that others dislike them. Some large classes offer a low-pressure context for learning and an opportunity to exercise independence in deciding what and how to learn[14]. Large classes offer greater flexibility in class participation and attendance than small classes[48]. Some students may find this attractive because it enables them to coordinate their academic and work schedules more efficiently. In some cases, students may prefer to work independently and may also feel more comfortable with the anonymity that large classes have. Finally, large classes offer nearly limitless opportunities for social contacts with other students, either to study or just to meet.

Learning Theories

Learning theories are a part of the effectiveness of student learning and provide a general interpretation for observations made over time, in order to address the challenges of helping learners succeed and to explain and predict behavior[25,33,60,68,77,84]. To understand the complex process of learning, in essence, the theory about human learning can be categorized into six broad paradigms: behaviorism, cognitivism, constructivism, experiential, humanistic, and social-situational learning theories[67].

Behaviorism is a theory that is concerned with the observable change in behavior[51]. Behaviorists believe that learning is provided by change in actions through an explorative process[20]. Behaviorism exposes individuals to external stimuli until a desired response is received. In the behaviorist theory, knowledge is transferred by the teacher while the learner is only a passive participant. *Cognitivism* emerged when researchers found out that behaviorism did not account for all types of learning[37]. According to this theory, knowledge can be viewed as a scheme, or "schema", that is, symbolic mental constructions that are organized or processed in the mind[64]. Learning occurs when there is a change in the learner's schemata; the learner is an active participant[81]. On the other hand, *constructivism* assumes that learning is a process of actively "constructing" knowledge rather than simply acquiring it[47]. It takes the learner's social, cultural and contextual conditions into consideration and theorizes that the learner constructs knowledge through experience[30]. In other words, learners tend to interpret new information through their contextual experiences and build on their existing knowledge from the conclusions reached during the assimilation of new knowledge and reflections on it[63]. *Experiential learning theory* is a holistic perspective on learning that combines experiences, perception, cognition and behavior[11,43]. The theory emphasizes the central role of experience in the learning process[4,38,60]. Learning is a continuous process grounded in experience. *Humanistic* is another theory of learning and prioritizes human needs and interests[44] in the learning process. This theory suggests that it is necessary to study a person as a whole, especially as an individual grows and develops over the lifespan[16]. Finally, *socio-situational* theorists emphasize that learning takes place in social relationships[69,86]. Social learning theories posit that people learn by observing others.

Out of these six theories of learning, constructivism theory has often been used as a model to construct a theoretical perspective in engineering education[19,41,74,87]. Among these six paradigms, researchers[40,41,74] believe constructivism aligns best with engineering education. It is a theory of learning founded on the premise that the reflection of our experiences will construct our own understanding of future knowledge, much like the purposeful, deliberate, and systematic nature of engineering, which requires reflection on past knowledge to construct future perceptions. There are several guiding principles of constructivism[30,41,47,63,74]:

1. Understanding comes from interactions with the environment. A learner's knowledge comes from his/her pre-existing knowledge and experience, and new knowledge is formed when connecting previous experience to the new content and environment.
2. Conflict in the mind or confusion is the stimulus for learning and determines the organization and nature of what is learned.
3. Knowledge involves social negotiation and the evaluation of the viability of individual understanding and past experiences.

Elements of Effective Teaching and Learning Using Student-Centered Pedagogy in Large Classes

Although there is no single, best method for addressing the effectiveness of student learning, especially in large classes, at least seven elements of effective teaching, suggested by numerous researchers (as discussed below), shape how much and how well students learn in this context.

The *first* element is careful design and preparation of the course[88]. Course design shapes students' experiences, the pathways through areas of content and the mechanism by which material is learned. In the absence of careful design and adequate preparation, students may have great difficulty in following the flow of material and course work. This problem is magnified in large courses because a greater number of students is more likely to become confused, particularly since they have limited access to the instructor for individualized assistance in explaining difficult material or in clarifying the relationships between different parts of the course[1].

A *second* important element to effective learning in large classes is the quality of the instructor's presentations to students[2]. Whether these are formal lectures, facilitated exercises or laboratories, or interactive conversations, the preparation and delivery of the presentations is critical to students' perceptions and grasp of the content of the course. Large classes typically rely heavily on some form of lecture or presentation[85]. Separate from other parts of the class, these presentations can either "make or break" learning, facilitating or hindering the process for hundreds of students. The level of enthusiasm the instructor communicates for the material and the clarity of ideas the instructor delivers will influence whether many students engage the ideas and commit to working hard over the course of the term in studying and learning[21].

A *third* aspect of large courses that effects how well students learn is the level of administration and management of the course[10]. Large courses present a host of unique administrative challenges that range from ensuring continuity among discussion sections led by different teaching assistants, to those associated with distributing and collecting students' examinations in a large lecture hall in a timely manner. The challenges are not trivial; they certainly influence how well students perform on many aspects of the course[36], and when teaching assistants make mistakes, they are often the subject of students' vocal complaints. More students will learn the material if the course is well organized and well managed.

Fourth, classes that incorporate some form of active or experiential learning engage students more effectively than classes that do not[54]. The traditional "lecturing/listening" model of teaching is typically less effective because students play a primarily passive role, taking little responsibility for making sense of the content or in applying it to the solution of problems[27]. Obviously, the challenge in large courses is finding mechanisms by which learning can be active and participatory. Traditional interactive exchanges between the instructor and students that may work well in seminars and small classes can rarely be used in classes of over 40 students. In large classes, students may participate in the learning process with one another or in experiences altogether outside of the classroom. In these types of experiences, the professor's role shifts from lecturer to facilitator, from expositor to coordinator[54]. Collaborative working groups among students, small group discussions in the lecture hall, and experiential learning opportunities remove the students from the role of passive learner, putting them in a participatory role[76].

An increasingly important *fifth* element of large classes is engaging students through the use of multimedia. For decades, instructors have relied on films, photographic images, and transparencies to convey ideas or to offer illustrations[24]. These are particularly important to teaching and to learning in large classes because of the diversity of student experiences and learning preferences. They offer students different "looks" at the material or visual experiences and, at the same time, provide the instructor with pedagogical stimuli that are likely to engage students, particularly those who are visually oriented[53,58,79].

Ensuring that graduate student teaching assistants are adequately prepared and supervised is a *sixth* element of effective teaching in large classes[26,57,61]. Although instructors use teaching assistants differently, many large courses are divided into lecture and recitation sections, with teaching assistants taking instructional responsibility for the latter. The obvious challenge is that most graduate students have little teaching knowledge and experience. Further, they may have little or no knowledge of the content of the course. Because teaching assistants often spend more time with students, individually and in smaller groups than the instructor in a large class, they must receive adequate preparation in course content and in how the material must be taught[29].

A *final* element related to how well faculty teach and how well students learn is assessment[80]. To what extent does the instructor incorporate assessment into his/her analysis of the course and student learning? At the heart of this issue is the idea that effective teaching must be informed with knowledge about what students learn and how they learn3[2,66,83]. In large classes this is particularly challenging because there are few ready mechanisms other than examinations and assignments for assessing whether students grasp the material or are engaged in the subject. Although exams do shed light on levels of student learning, they are not necessarily informative about the problems students may experience in the course or the precise causes of their problems. Traditional exams and assignments do not necessarily reveal whether the instructor and teaching assistants offer perspectives on the course material that are consistent or complimentary[32]. They also do not necessarily reveal whether poor student performance is the result of inadequate preparation by the students or insufficient clarity on the part of the instructor, such as in his/her presentations, assignments, and material[80]. Finally, the information that traditional examinations provide is often not timely because the exams are retrospective, shedding light on work and material in weeks past rather than in the present. The most effective assessment centers on levels of student learning34. To the extent that assessment is routine and continuous throughout a course (not simply at the end of the term), it will prove most useful to solving students' leaning difficulties or problems80. Immediately knowing that problems exist in a course enables the instructor to respond to difficulties "as they arise". However, this approach to assessment implies high levels of student participation in the course. For example, students must routinely comment on or evaluate presentations, assist in the development and analysis of examinations and assignments, or participate collaboratively with the instructors and teaching assistants. The course becomes somewhat versatile, always changing in character and form in response to problems and issues in student learning that arise over the course of the term. The difficulty, of course, is that large classes, heavy student participation can be enormously burdensome for the instructor, given the obvious logistical challenges[83].

Role of Class Size in Effective Teaching and Learning Using Student-Centered Pedagogy

One of the main criticisms of large classes is that student learning in large classes is shallow[1]. Faculty members give lectures and students take notes without much association or interaction; material is learned for tests and then immediately forgotten by the end of the term. Since deep learning can only happen when students are able to communicate with the educator, many faculty members look for methodologies to consolidate more dynamic learning into large classes[42,55,56].

Although numerous researchers [2,10,21,39,42,46,72,85] have recommended creative methods for dynamic learning inside the classroom, as class size increases, most teachers agree that the degree of cooperation or participation among students decreases. Too often class size determines the strategies used to transmit information to students. Recent studies and research propose that dynamic learning can work in both large and small classrooms. An ongoing assortment of research papers focused on dynamic learning[2,5,7,10,21,42,85] proposes that class size has little effect in the success or failure of learning. Smaller classes are not required for significant learning experiences and outcomes, and that dynamic learning can be practiced even in large classes.

Methods

Data Analysis

This preliminary analysis of the study used a descriptive and correlational research design to investigate the dynamics of course continuity from prerequisites to target courses. Quantitative data collection was employed which allowed the data to be quantified and analyzed. To ensure confidentiality, a dataset was built using student identification numbers, however, as soon as the dataset was completed, all student identifiers were removed prior to any analysis and all results were presented in aggregate form, such that no individuals can be identified. This ensured that the investigators in this project cannot identify the individuals to whom the data pertain.

		Frequency (n)	Percent (%)
Gender	Men	187	80
	Women	44	19
	Prefer Not to Answer	4	1
	ISMB		
Major	Aerospace Engineering	*8*	*3*
	Civil Engineering	41	17
	Mechanical Engineering	97	41
	NON-ISMB		
	Biomedical Engineering	13	6
	Chemical Engineering	*2*	*1*
	Computer Engineering	37	16
	Electrical Engineering	23	10
	Materials Engineering	7	3
	UNDECLARED	7	3
Work Commitment	Working	128	54
	Not Working	107	46

Table 1. Frequency by Gender, Major, and Work Commitment

Population

The population sample of this study was engineering students enrolled at SJSU, located in Silicon Valley, ranked ninth in the Western United States in terms of ethnic diversity among colleges and universities, conferring bachelor's and master's degrees (SJSU website, 2018). The sample population comprised of students enrolled in mechanics of materials (CE 112), dynamics (ME 101), and introduction to circuit (EE 98) courses in spring 2017. Demographic characteristics in this study included a total of 235 students –frequency by gender, major and work commitment is shown in the table below.

The students' majors include aerospace engineering, civil engineering, mechanical engineering, biomedical engineering, chemical engineering, computer engineering, electrical engineering, and materials engineering. Majors were grouped into two categories: "intensive solid-mechanics based majors" (ISMB majors) and "non-intensive solid-mechanics based majors" (Non-ISMB majors). Aerospace engineering, civil engineering, mechanical engineering majors were categorized as ISMB. Biomedical engineering, chemical engineering, computer science engineering, electrical engineering, and materials engineering were categorized as non-ISMB majors.

Procedure, Measures, and Results

Data were obtained in the spring of 2017 via surveys administered at the end of the semester in 3 fundamental engineering courses: mechanics of materials, dynamics, and introduction to circuit. In the semester the surveys were administered, 172 students were enrolled in mechanics of materials, 183 enrolled in dynamics, and 236 enrolled in introduction to circuit. Each course was divided into 3 smaller sections for lectures –thus enrollment in each section is around 60-80 students, which still fits the category of large class size. Out of this population of students, 54 students (31%) in mechanics of materials, 68 students (37%) in dynamics, and 113 students (48%) in introduction to circuit, responded to our surveys.

Research Question 1: *Do gender, major, and work commitment contribute to failure rates in engineering courses such as mechanics of materials, dynamics, and introduction to circuit at SJSU?*

Due to violations of normality when examining the histogram of the dependent variable, the results were validated using a nonparametric independent samples test, as shown in Figures 1-3. The Mann-Whitney U-test was used to assess for significant differences. It is the non-parametric equivalent of the independent samples t-test. Because the test does not assume any properties regarding the distribution of the dependent variable in the analysis, the Mann-Whitney U-test was the appropriate analysis to use when analyzing dependent variables in this study. Results show that indeed there is no statistically significant difference in gender, major, and work commitment as measured through final course grade in all 3 courses –thus the second research question, comparisons of learning dynamics of a classroom (large versus small) were analyzed.

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of **Final Course Grade** is the same across categories of **Gender**.	Independent-Samples Mann-Whitney U Test	0.173	Accept the null hypothesis.
2	The distribution of **Final Course Grade** is the same across categories of **Major**.	Independent-Samples Mann-Whitney U Test	0.161	Accept the null hypothesis.
3	The distribution of **Final Course Grade** is the same across categories of **Work Commitment**.	Independent-Samples Mann-Whitney U Test	0.063	Accept the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 1. Results of nonparametric independent samples tests of Mechanics of Materials.

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of **Final Course Grade** is the same across categories of **Gender**.	Independent-Samples Mann-Whitney U Test	0.093	Accept the null hypothesis.
2	The distribution of **Final Course Grade** is the same across categories of **Major**.	Independent-Samples Mann-Whitney U Test	0.111	Accept the null hypothesis.
3	The distribution of **Final Course Grade** is the same across categories of **Work Commitment**.	Independent-Samples Mann-Whitney U Test	0.082	Accept the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 2. Results of nonparametric independent samples tests of Dynamics.

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of **Final Course Grade** is the same across categories of **Gender**.	Independent-Samples Mann-Whitney U Test	0.064	Accept the null hypothesis.
2	The distribution of **Final Course Grade** is the same across categories of **Major**.	Independent-Samples Mann-Whitney U Test	0.141	Accept the null hypothesis.
3	The distribution of **Final Course Grade** is the same across categories of **Work Commitment**.	Independent-Samples Mann-Whitney U Test	0.073	Accept the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 3. Results of nonparametric independent samples tests of Introduction to Circuit.

Research Question 2: *Does taking prerequisite courses at community college versus UNIVERSITY influence the outcome or performance in the target courses?*

In SJSU, as in most engineering colleges, math and physics prerequisites play a major role in students' success. Figure 4 below summarizes this conclusion. Each of the 3 courses offered has either a math or physics prerequisite. The prerequisites for mechanics of materials, dynamics, and introduction to circuit are ordinary differential equation, calculus II, and general physics of electricity and magnetism, respectively. Students are free to take these prerequisites in either a community college or SJSU. Grades of A+, A, and A- earned are pooled into one group called the "As". The "Bs" and the "Cs" are grouped in a similar fashion, accordingly. Our analysis revealed that grades in math or physics prerequisites taken at SJSU has low bearing on students' success – 14%, 27%, and 36% of the Bs students taking the math or physics prerequisite course at SJSU failed mechanics of materials, dynamics, and introduction to circuit, respectively and 28%, 25%, and 52% of the Cs students taking the math or physics prerequisite course at UNIVERSITY failed mechanics of materials, dynamics, and introduction to circuit, respectively. Compare this with 13%, 14%, and 15% of the Bs students taking the math or physics prerequisite course at a community college failed mechanics of materials, dynamics, and introduction to circuit and 33%, 28%, and 36% of the Cs students taking the math or physics prerequisite course at community colleges failed mechanics of materials, dynamics, and introduction to circuit, respectively. The comparison is between taking prerequisite courses within the university or in a community college. All the mechanics of materials, dynamics, and introduction to circuit courses were taken in the college of engineering at UNIVERSITY. In general, the number comparisons between taking the prerequisite courses in community college or within the university do not seem to be striking for mechanics of materials and dynamics – however, it is markedly different for introduction to circuit. The results showed that 36% of students who took the physics prerequisite (electricity and magnetism) at SJSU for introduction to circuit and received a B grade (B+, B, B-) failed the course – compare this with 15% of students who took the physics prerequisite at a community college. It also showed that 52% of students who took the physics prerequisite at SJSU for introduction to circuit and received a C grade (C+, C, C-) failed the course – compare this with 36% of students who took the physics prerequisite at a community college. Grade of a B or a C are passing grades – however with as many as 1/3 to 1/2 taking the physics prerequisite at SJSU failed the introduction to circuit course is quite astonishing. Is it possible that the comparison between taking the physics prerequisite within the university and community college must be based on size of classrooms and the complexity that comes with it? Is it also possible that the failure rates in engineering could be decreased if introductory engineering courses are given with a simple move to smaller class size? The urgency for a new paradigm in teaching fundamental engineering courses in the college of engineering at SJSU is imminent. In this preliminary analysis the prerequisite course to introduction to circuit analyzed was general physics of electricity and magnetism, which has strong and direct relationship to the course. The prerequisite courses to mechanics of materials and dynamics were differential equations and calculus II, respectively – these do not have as strong and direct relationship to the target courses. Thus, more in-depth analysis will be used to understand the complex failure rates in mechanics and dynamics courses, in a second paper of this study.

New Insights in the Study

Next, we investigated the students socioeconomic background, work load versus course performance, health issue, and learning environment. We categorized students based on their performance in the course – students who failed are labeled as "DFW" for no passing grades of D+, D, D-, F, and W (withdraw) and students who did not fail are labeled as "non DFW". Below are the results:

Figure 4 categorized students who failed the class during spring 2017 (DFW students) and those who did not (non DFW students). Most of the DFW students in our study came from low socioeconomic background, less than high school to high school-educated mothers. At the same time there were also DFW students from middle socioeconomic background whose mothers have 4 year college degrees as well as high socioeconomic background whose mothers have masters degrees. Failure rates in all 3 courses in this study did not depend on socioeconomic status and mother's education.

Figure 5 categorized students in all 3 courses in the study based on their work load and grade in the course. There is no statistical differences in course performance between students who do not work and those who work 1-20 hours each week. There were statistical differences with those students working more than 20 hours each week – only in 2 of the 3 courses (dynamics and introduction to circuit). This is of course expected considering the academic rigor the engineering curriculum is known for – the more the students work, the lower their performance was in the course.

Figure 6 categorized students in all 3 courses in the study based on their health issue and ethnicity. There were almost no student across the black, Hispanic, white, and other categories who were experiencing health issues and who were also categorized as DFW students. There were several students in the Asian category, who shared their health issues, and who also fall in the DFW – very

		UNIVERSITY (%)	Community College (%)
Mech. of Materials	As (grades of A+, A, A-)	7	0
	Bs (grades of B+, B, B-)	14	13
	Cs (grades of C+, C, C-)	28	33
Dynamics	As (grades of A+, A, A-)	7	13
	Bs (grades of B+, B, B-)	27	14
	Cs (grades of C+, C, C-)	25	28
Intro. to Circuit	As (grades of A+, A, A-)	12	0
	Bs (grades of B+, B, B-)	36	15
	Cs (grades of C+, C, C-)	52	36

Table 2 . Percentages Comparison of Failure Rates

few, and not statistically significant to the other categories. The majority of the students in the study were in the category of "not failing the course (non DFW) and not experiencing any major health issue". So far, in figures 4 through 6, failure rates (DFW) cannot be attributed solely by ethnicity, socioeconomic status, mother's education, work load, nor health issue. Perhaps these 5 elements combined together are somewhat predictors of failure rates, but not each of them individually.

Next, we investigated the students stress levels in 3 areas: financing their education, balancing family obligations and school, and coursework. The results are summarized in figures 7 through 9. The red dots represent students who did feel major stress in life in the 3 areas asked in the study and the grey dots represent students did not. The majority of the students express no stress in the areas of financing their education and balancing family obligations and school –they instead found stress in their coursework. They were not stressed due to their socioeconomic status, mother's education, work load, health issue, financing their education, nor balancing family obligations and school –they were stressed in their coursework. This finding was a significant breakthrough in our study and our research saw it as a tremendous opportunity in changing the paradigm in teaching these fundamental engineering courses. This paradigm is outlined in the next section below.

Recommendation

A new paradigm is needed to cater to the very complex dynamics of student learning in Universities. The students in such institutions are juggling classes, jobs or family or both. Most of our education system is not built to cater to the needs of working students, and the results show 30% failure rate annually in fundamental engineering courses. This is an unfortunate reality. Active learning should no longer be just an option –it must be treated as the key ingredient in attempting to start solving the repeated failure catastrophe. Active learning contains many interactive elements, including weekly lectures, in-class activities, online activities[71], and hands-on lab exercises –

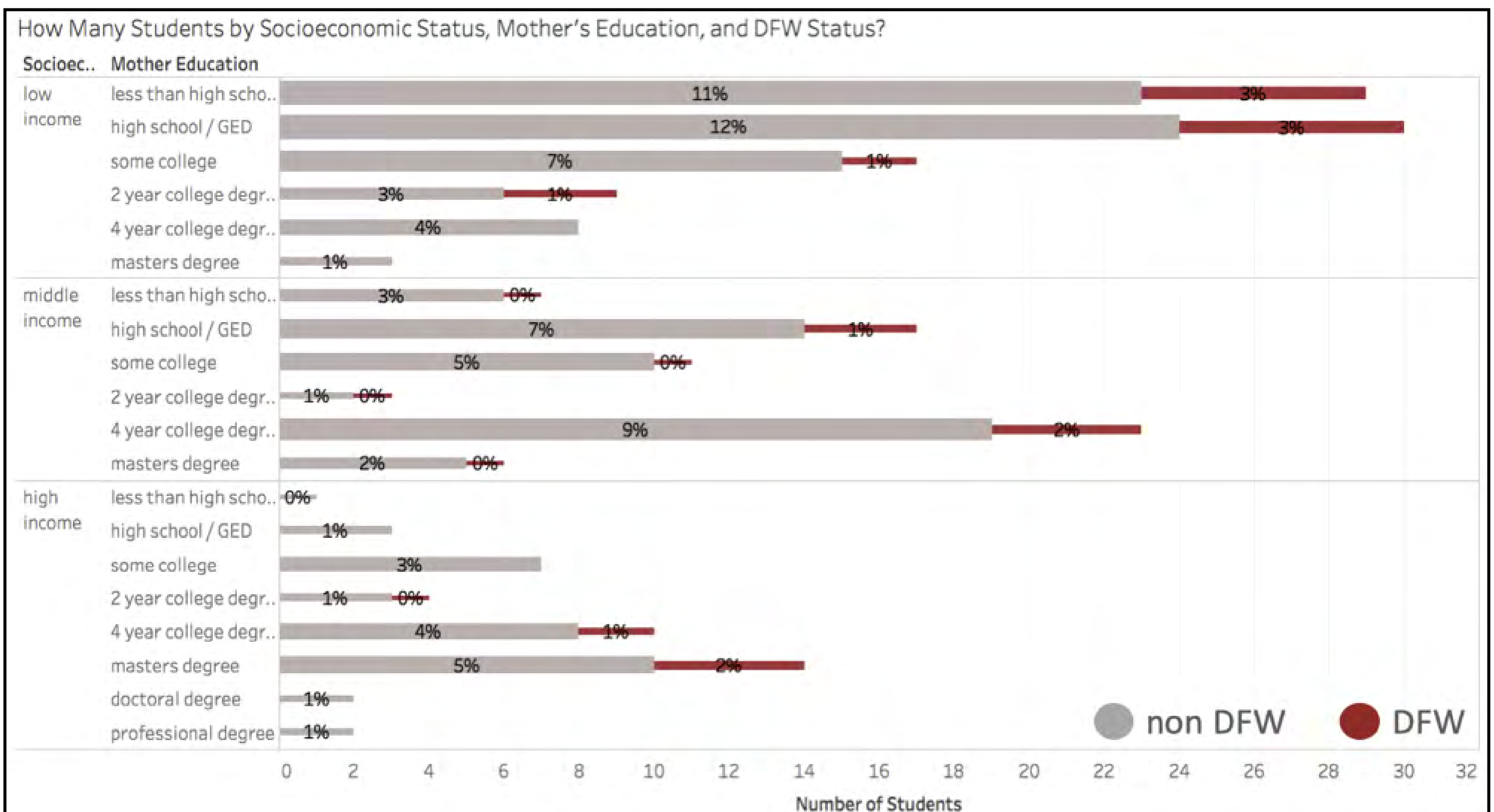


Figure 4. Results of all students in the study on socioeconomic status and mother's education.

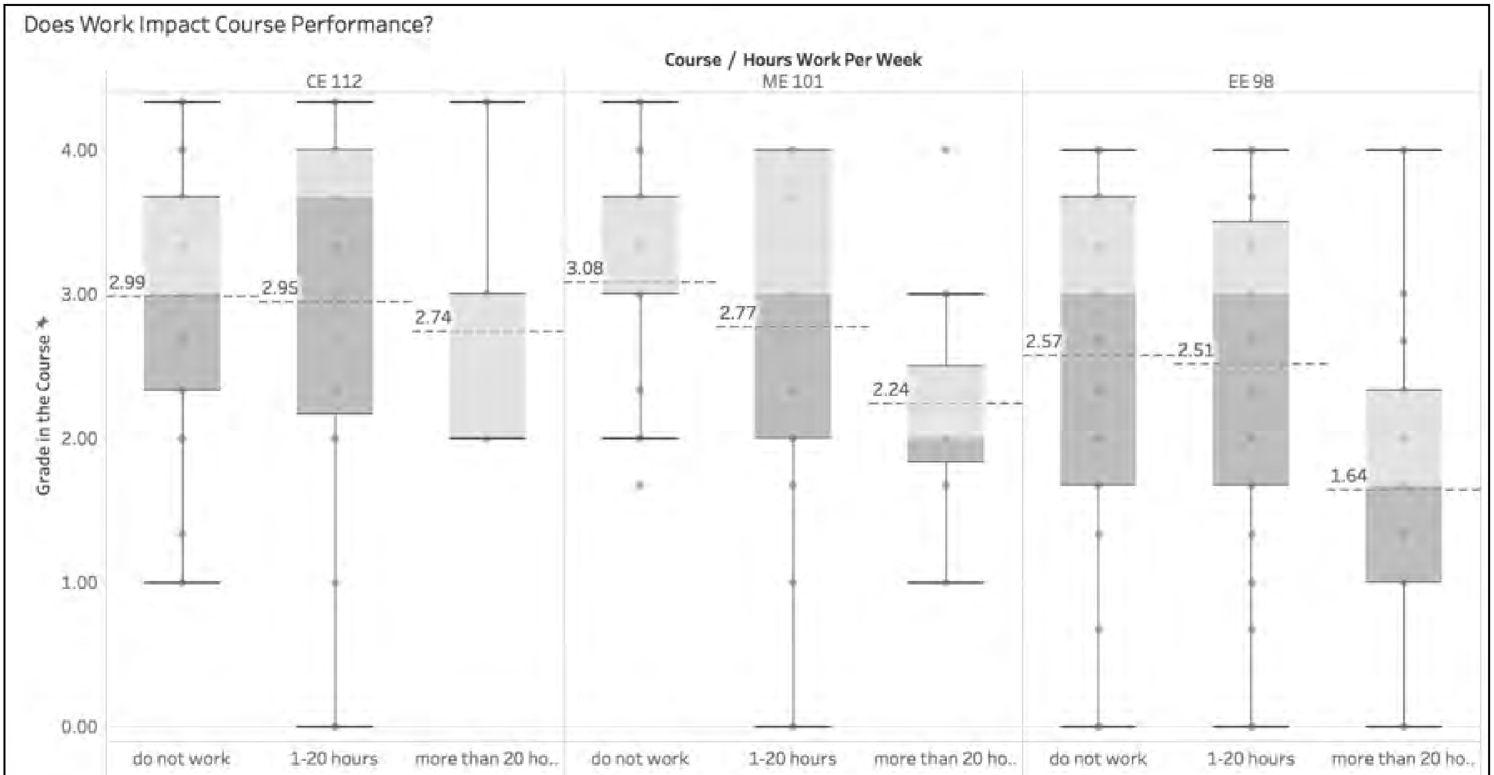
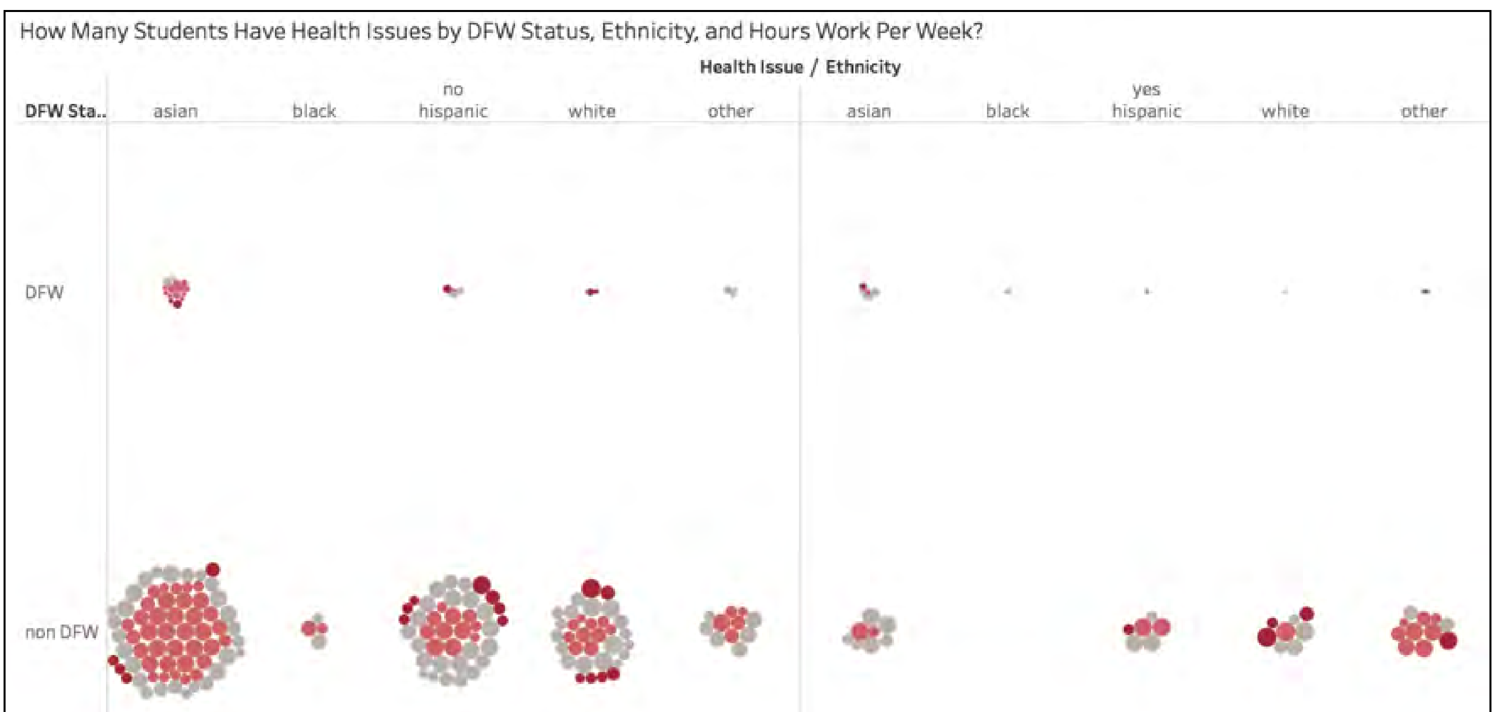


Figure 5. Results of all students in the study on work load versus course performance.

all done during the 75-minute class time in each lecture, not changing any curriculum structure. Each element of the new paradigm is described below. This paper uses the case study of the author who teaches mechanics of materials and have also designed a new paradigm in teaching these courses. For the purpose of convincing the reader on what this new paradigm entails, examples below are that of mechanics of materials. This paradigm was created and introduced as a teaching method for mechanics of materials during the author's postdoctoral studies at Stanford University under the guidance of Professors Sheri Sheppard and Sarah Billington. However, these elements may easily be adopted for dynamics and introduction to circuit –which will be published in the second paper of this study by the author.

Lecture

Class will be held two times per week for 110 minutes each period –with no change to credit unit hours. Lectures, in general, should cover about 20 minutes of class and must be planned with a minimalistic approach, focusing on the essential points. The remainder of class period will be designed for in-class activities, including problem-solving as well as hands-on lab experiments.



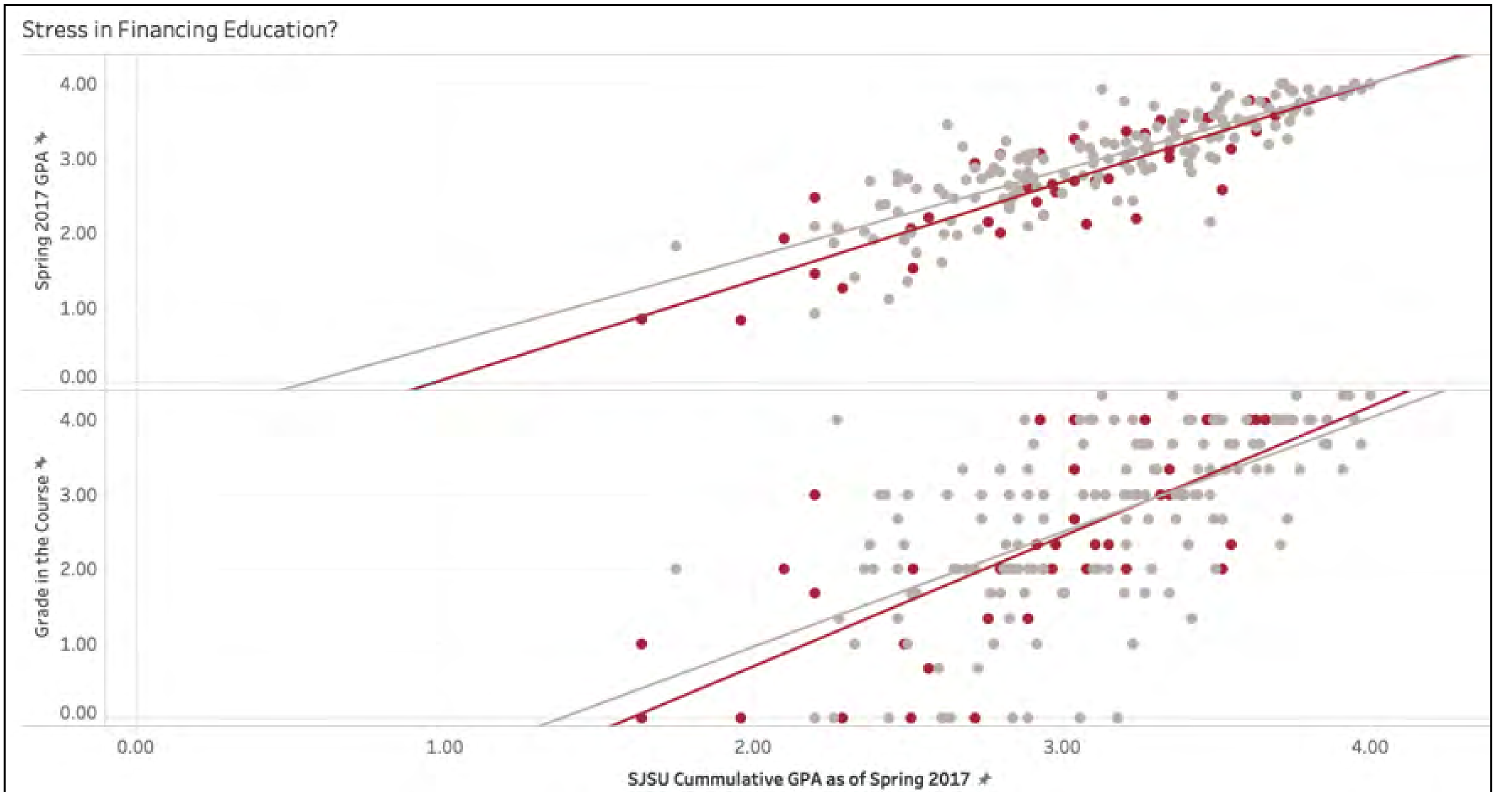


Figure 7. Results of all students in the study on stress in financing education.

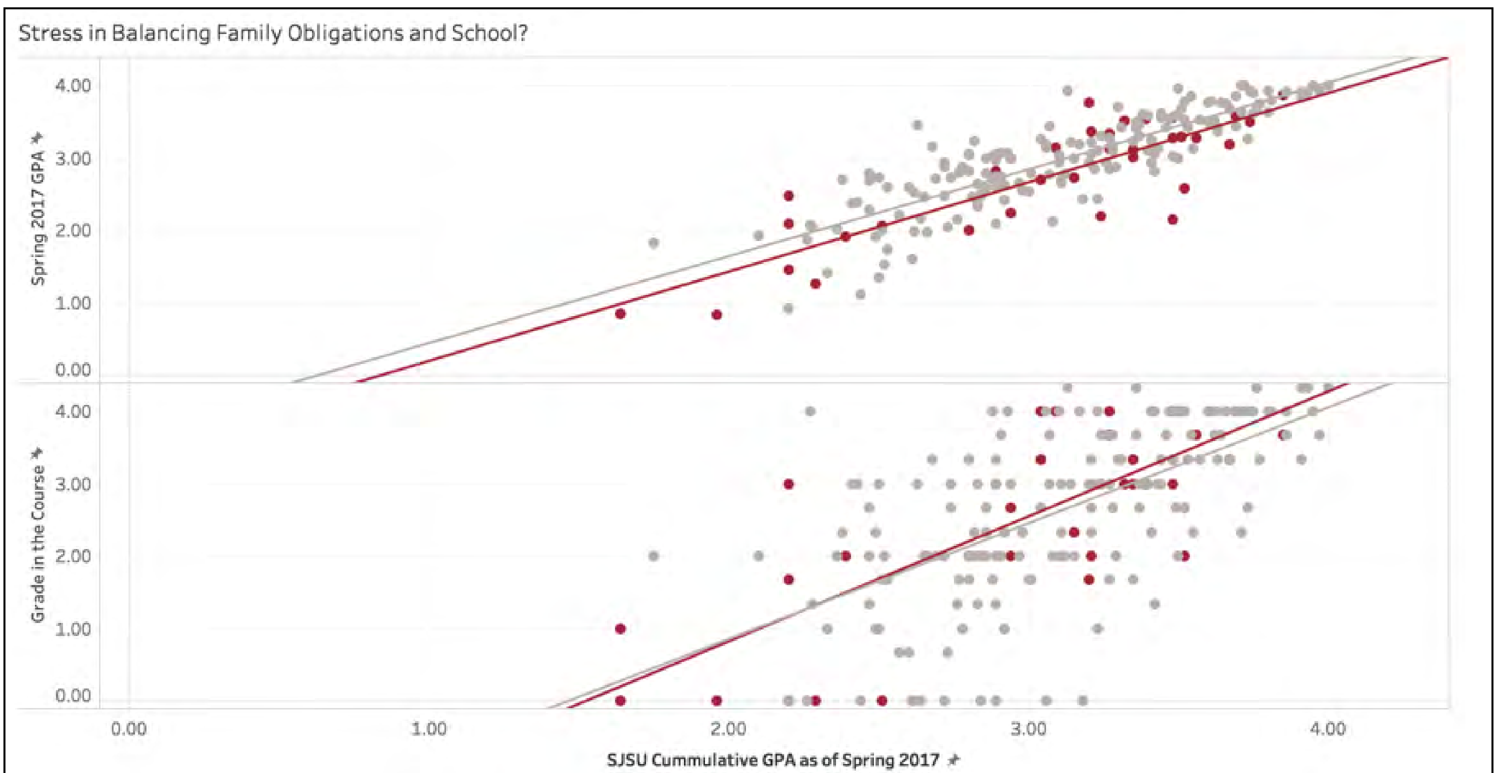


Figure 8. Results of all students in the study on stress in balancing family obligations and school.

In-Class Activity

In-class activities shall be based on active-learning strategy, in which students work on a problem posed by the instructor –at times individually and at other times in pairs or in groups, before participating in a class-wide discussion. The objectives of these activities is not only to allow students to express their reasoning, reflect on their thinking, and obtain feedback on their understanding; but also to "catch" or identify unengaged and uncovered pre-conceptions.

Hands-On/Lab Activity

Hands-on lab activities for class shall be designed based on research using the approach of scenario-based learning pedagogy. Scenario-based learning involves real world hands-on experience where students were given a scenario problem to solve. Each

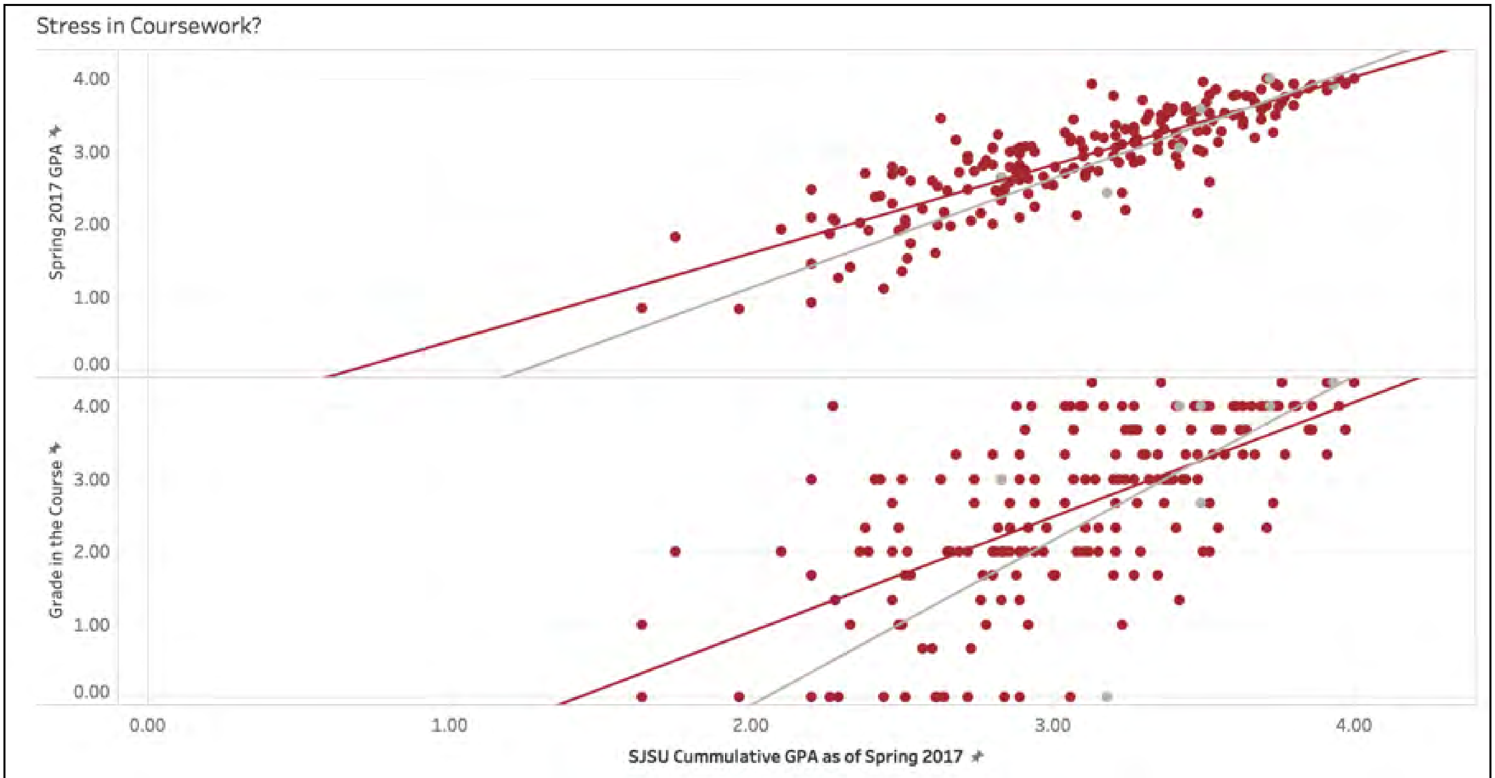


Figure 9. Results of all students in the study on stress in stress in coursework.

hands-on activity will take about 40-50 minutes of class time. Several examples of in-class activities are shown in Figure 5 below.

Online Activity

During the mechanics of materials course, students must be assigned online activities as part of their homework. Each online activity shall take approximately 35-45 minutes to complete and students shall complete them outside of class at their own convenience. Questions in the online activities will be created using a surveying tool, Qualtrics, and will be designed to be interactive. The questions placed strong emphasis on applying fundamental understanding of solid mechanics, such as drawing free-body diagrams and drawing shear force and bending moment diagrams, and comparing with real-world examples and scenarios, rather than memorizing definitions and facts. Qualtrics allows for automatic assignment grading, student progress tracking, and performance analytics, all of which will be linked to the class learning management system. Each question shall be designed to provide interactive feedback to increase student learning and retention. Short videos will be placed strategically throughout the sessions of online activities to aid and remind students of fundamental concepts learned during class. The online activities are meant to provide active-learning interventions in which students practiced problem-solving with hints and feedback for increasing understanding of fundamental concepts of introductory solid mechanics. Example questions of online activities are shown in Figure 6.

A pilot course, which will include the aforementioned elements, in mechanics at the college of engineering in San Jose State University (SJSU) will be offered in Spring 2019. The author of this paper will teach the course. The hypothesis is that the students participating in this course redesign, particularly in the longitudinal study in mechanics of materials, dynamics (after the pilot course has been offered), and introduction to circuit (after the pilot course has been offered) will remain in engineering through graduation, will earn higher grade point averages in engineering, and will likely develop more positive attitudes about engineering and about their own capabilities

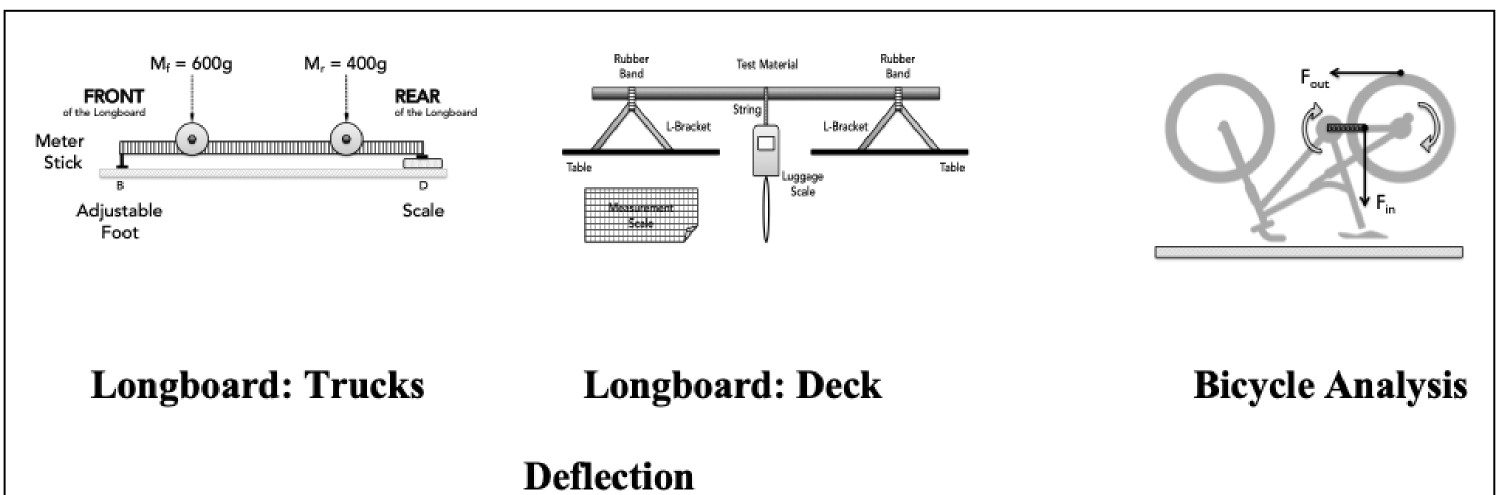
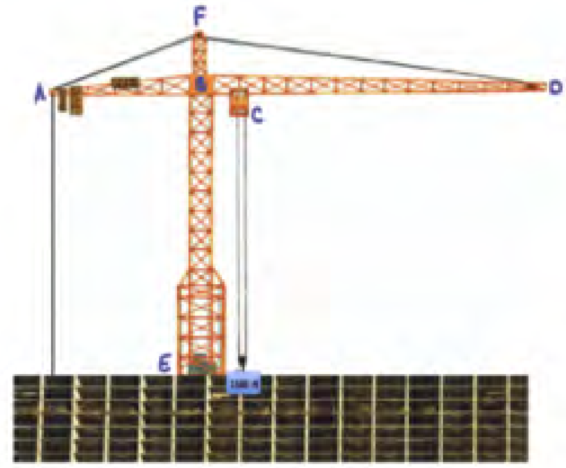
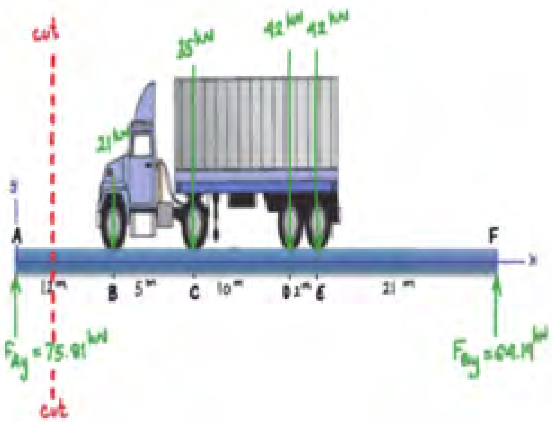


Figure 5. Hands-On Lab Examples

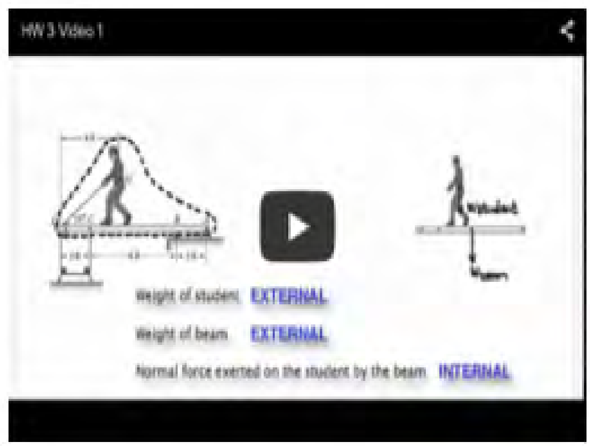
"What kind of force is the weight drawn?"[6] of the longboard?"



"How should the fixed support at E be?"



"Cut anywhere between segment A and B, what kind of function would the shear force diagram be?"



Video of Types of Forces

Figure 6. Online Activity Examples

than do students who go through the traditionally taught curriculum.

Limitations Of Study

The primary aim of this preliminary study was to research student backgrounds, classroom dynamics, and prerequisite courses taken. There might be a constrained generalizability and a potential for bias from future investigations because of the absence of randomization of the chosen sample participants, because of the way that courses were chosen by students or by their academic supervisors. Additionally, class size is absolutely one contrast between community colleges and SJSU, as SJSU class sizes are essentially larger. In any case, there are various different contrasts between the subjects in the study that may likewise help clarify the difference in academic performance, for example, financial status, socioeconomic backgrounds, parents education, and ethnicity. It is necessary to exercise caution while applying the findings of this study to different students populations. The study or its findings cannot be extrapolated or generalized without considering many other extraneous or related factors.

Definitions Of Terms

1. *Large classes* refers to classes of more than 40 students[15].
2. *Passive learning* refers to the typical lecture format where the instructor speaks in front of the students and the class sits facing the instructor. Interaction between the teacher and students often appeared stiff and limited to questions and answers. The typical lecture format limited interaction among students during class time.
3. *Active learning* refers to something "other than" the traditional lecture format. The concept of active learning is simple: rather than the teacher presenting facts to the students, the students play an active role in learning by exploring issues and ideas under the guidance of the instructor. Instead of memorizing, and being mesmerized by a set of often loosely connected facts, the student learned a way of thinking, asking questions, searching for answers, and interpreting observations.

This is an ongoing study for the college of engineering at SJSU and the paper serves as a preliminary analysis. The author hopes to publish the second part of this paper in next year. Future work might be to test the hypothesis that the distribution of final course grades would remain (or would not remain) the same, no matter where the relevant prerequisites were taken.

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