2018 ASEE Annual Conference & Exposition
June 24–27, 2018 Salt Palace Convention Center Salt Lake City, UT

Paper ID #21187

Using Mobile Learning to Improve Low Success Rate in Engineering Courses

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Abstract

Mechanics of Solids is a fundamental core course in Engineering. In San Francisco State University (SFSU), it is a prerequisite course for six Civil Engineering (CE) and seven Mechanical Engineering (ME) courses. Being a prerequisite for these courses, Mechanics of Solids is a very critical course for both Civil and Mechanical students. However, Engineering doesn't come easy to everyone. Lack of practical examples, accessible materials, timely guidance and feedback from instructor are identified as three of the reasons for the low success rate of this course according to the past course surveys and evaluations. Besides, it has been observed that students often miss the global picture and connections between various concepts due to the large number of topics involved in the course. Furthermore, students come with different prerequisite knowledge, which is difficult to accommodate with the limited amount of class time.

To combat these challenges, a series of strategies designed upon mobile technologies are developed and implemented at SFSU. These include recorded review videos to help students review prerequisite concepts, a series of interactive mobile learning apps to help students consolidate and practice gained knowledge, and virtual office hours to provide timely and easily accessible guidance and feedback to students. The highly interactive and concept-rich mobile knowledge apps are partially developed and used as complementary materials to engage students and stimulate active learning. Through these mobile apps, students can visualize complex concepts, create unlimited practice examples to consolidate the knowledge, and connect various concepts with an overall picture of the course.

Pre- and post- surveys were conducted to evaluate the effectiveness of the developed strategies to improve the students' learning outcomes. Survey results demonstrated the improvement in participants' knowledge competence after using the intervention. In addition to the surveys, the final grades of the students in Spring 2017 are compared to those from Fall 2014 to provide a direct performance comparison with and without using the intervention. The obtained information will be utilized to guide the future development and refinement of the tools, as well as understand what strategies could be used to better fit the need of the new generation learners.

Introduction

Mechanics of Solids is a fundamental core course in both Civil Engineering (CE) and Mechanical Engineering (ME). As evidence, it is a prerequisite for courses such as Experimental Analysis (CE & ME), Structural Analysis (CE), Soil Mechanics (CE), Construction Engineering (CE), Fundamentals of Composite Materials (CE & ME), Mechanical and Structural Vibrations (CE & ME), Material & Manufacturing processes (ME), Applied Stress Analysis (ME), Finite

Element Methods (ME), and Finite Element Methods (ME) at SFSU university. Topics covered in Mechanics of Solids include shear and bending moment diagrams, bending and shear stresses analysis, stress transformation and failure theories, beam deformation, column buckling, torsion, and elastic and ultimate resistance of materials.

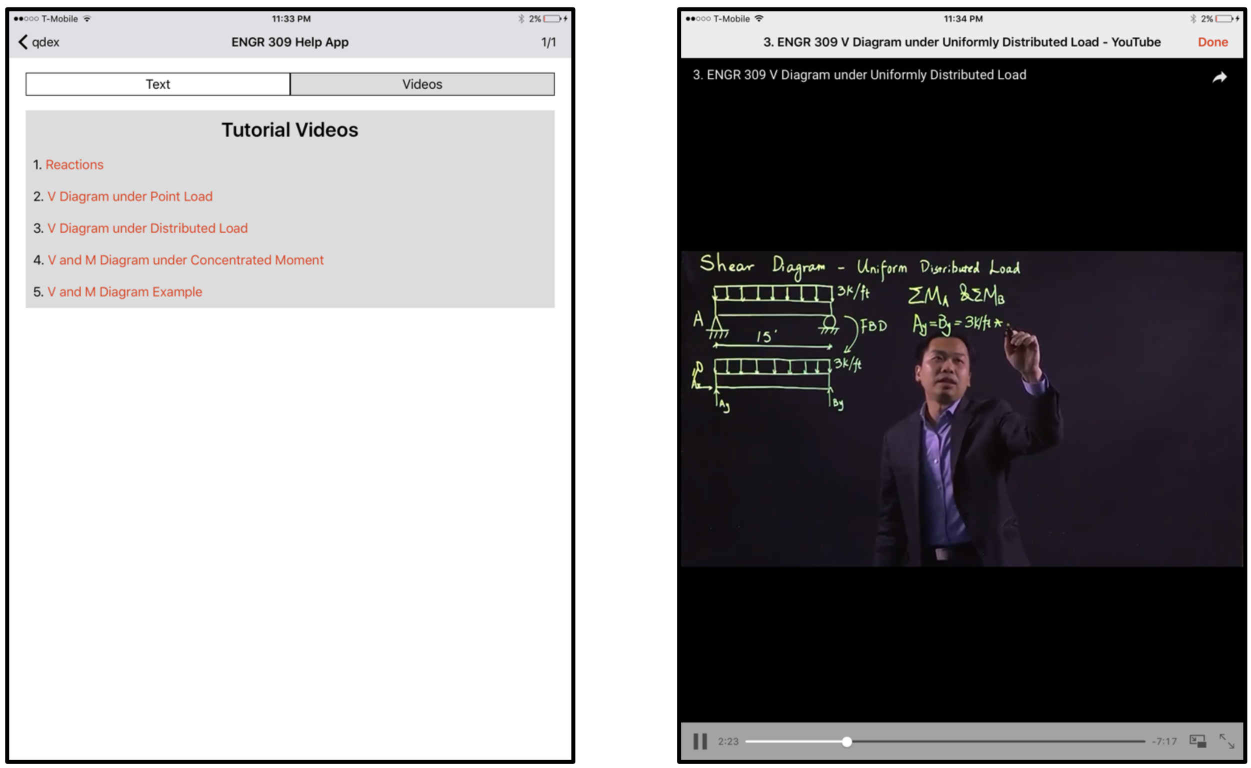
Engineering doesn't come easy to everyone. Lack of practical examples, accessible materials and timely guidance and feedback from instructor are identified as three of the reasons for the low success rate of this course (average D, F, W grades of 13.22% in the past 7 years) according to the past course surveys and evaluations. Besides, it has been observed that students often miss the global picture and connections between various concepts due to the large number of topics involved in the course. Furthermore, students come with different prerequisite knowledge which is difficult to accommodate with the limited amount of class time.

The advancement of technologies provides an opportunity to help on these challenges. It is estimated that there are over 7 billion mobile phone subscriptions worldwide [1]. Although mobile phone subscription doesn't necessarily reflect the number of mobile phone owners since there are multiple mobile subscriptions for individual people and for businesses, it does reflect the prevalent usage of mobile devices. These devices have prolific use in our everyday life for communication, access of information, and entertainment. Besides, mobile devices are beginning to be used in all levels of education because of their easy accessibility and increase in computational power [2-7]. This rise in popularity can be seen with increasing number of implementations in higher education in the past decade [8]. Recent studies have shown that a large majority of students in higher education own a smart device (phone or tablet) and they have accepting attitudes towards incorporating these devices in their education [9-10]. Mobile learning provides students a unique opportunity to be able to bring the classroom anywhere they go, however, implementation of mobile devices in learning environments needs to be done with care and foresight to avoid creating learning environments that don't benefit students. Frameworks have been developed to help educators deploy student friendly mobile learning environments. Criteria for these educational environments include availability, quick response, flexibility, scalability, usability, maintainability, functionality, reliability, connectivity, performance, user interface, and security [11].

Proposed Solution

A series of strategies designed upon mobile technologies are developed and implemented at SFSU to improve student learning for the Mechanics of Solids course. These include recorded review videos to help students review prerequisite concepts, a series of interactive mobile learning apps to help students consolidate and practice gained knowledge, and virtual office hours to provide timely and easily accessible guidance and feedback to students. In the following, each of these strategies will be explained in detail.

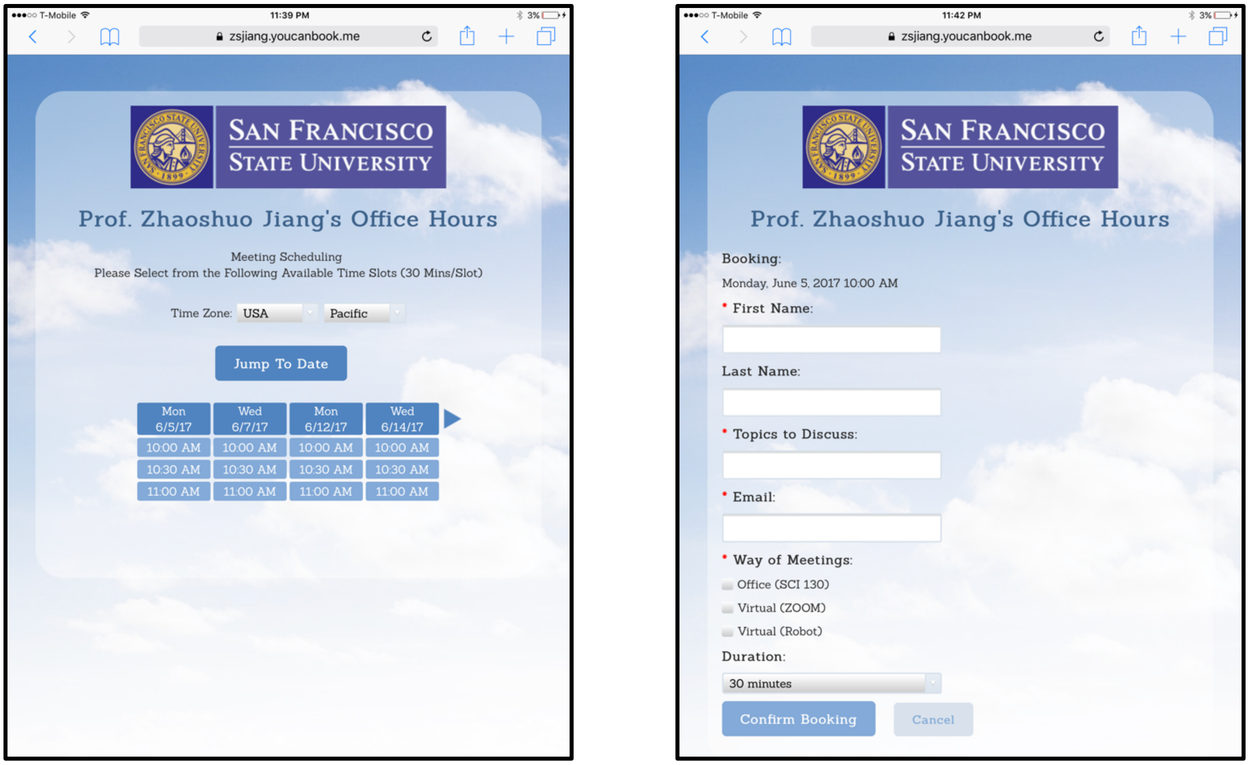
Recorded Review Videos - It is common to have students with different levels of prerequisite knowledge. To accommodate that, instructors often need to sacrifice valuable classroom time to review prerequisite content. As part of the course redesign efforts, a series of videos were created for students to review the prerequisite knowledge before going to the classroom. To allow for a more engaged, natural, and interactive viewing experience, the Learning Glass technology [12] was adopted to produce the videos. The Learning Glass was developed by Prof. Matt Anderson at San Diego State University. It is a transparent whiteboard paired with a lecture capture system, which allows the instructor to write normally, left to right. The recorded image is flipped so students can view the notes correctly through a monitor [12]. The recorded videos are embedded in the interactive mobile apps (see the following section for details) developed particular for this course as shown in Fig. 1, and they are accessible to students through their smart portable devices (e.g. smartphone and tablets) anywhere at any time.



a) *Help* App – Videos   b) Recorded Review Video – Learning Glass

Figure 1. Recorded Review Videos

Virtual Office Hours - It is not unusual that students do not make full use of the office hours until quizzes and exams. Reasons they typically provided were either too much trouble to come to campus only to ask a few questions or the time conflict with other scheduled classes. To remove these barriers and better serve the students' need, an online booking system (e.g., youcanbook.me [13]) is set up together with multiplatform teleconferencing tools (e.g., ZOOM [14]) to provide students timely face-to-face guidance experience without the need for them to take an actual trip to the instructor's office.



a) Virtual Office Hour –Interface b) Virtual Office Hour –Required Inputs

Figure 2. Virtual Office Hour - Booking System

To encourage more students to participate, a telepresence robot is integrated as an option to meet with the instructor. The telepresence robot, Double, is built by a technology startup company, Double Robotics [15]. It is a remote-controlled robot stand that works together with an Apple iPad to provide real-time control and communication. Through an app in a mobile device, users can remotely control the Double to move around and communicate interactively with its surroundings in real-time. In addition to the gamification aspect, the controllable robot, will provide students authentic sense of "in-person" participation. The booking system for the virtual office hour is shown in Fig. 2.

Interactive Mobile Learning Apps - With the advancement of technologies, mobile devices such as smartphones and tablets have become part of our daily life. To take advantage of that to improve student learning, intuitive and innovative mobile knowledge apps are utilized to transform conventional static training documents into highly interactive, concept-rich resources that fully exploit the convenience, power, and usability of modern smart mobile devices. The intent is to use these apps as supplemental materials which engage students and stimulate critical thinking and active learning.

All mobile apps were developed using a mobile development framework called qdex Play™, which is provided by a leading educational equipment provider, Quanser Inc. [16]. This mobile development framework aims to transform static conventional teaching documents in to highly interactive mobile apps. One great feature of using qdex is that the apps developed via this platform are directly usable in both Android and iOS devices without modifications, thus operating software (OS) of the students' devices does not dictate accessibility.

A total of eight mobile apps as listed in Table 1 are planned for the course. Six apps, *Bending*, *Deflection*, *Stress*, *Torsion*, *Axial*, and *Pressure Vessels*, will provide students the opportunity to set up their own practice problems and get instant feedback on the solutions. These apps allow students to explore and master the concepts covered in the course by giving them ample opportunity to practice outside the classroom.

Table 1: List of Mobile Learning Apps

App	Concept Covered	Status
Main	Global picture of the course and connections to various apps	Developed
Help	Course materials and recorded review videos	Developed
Bending	Shear and moment diagrams of member under bending	Developed
Deflection	Deformation of beams	In progress
Stress	Normal & shear stresses and their transformation	Developed
Torsion	Stress and strain under torsion	Developed
Axial	Stress and strain under axial load	In progress
Pressure Vessels	Stresses of vessels under pressure	In progress

A common concept map idea proposed by Egelhoff and Burns [17] which combined the principles of mind maps, concept maps and heuristics is adopted as a main flow to design and connect different mobile knowledge apps. The common concept map used in the course is shown in Fig. 3. This is also used to help students connect various concepts, giving them an overall view of the course content.

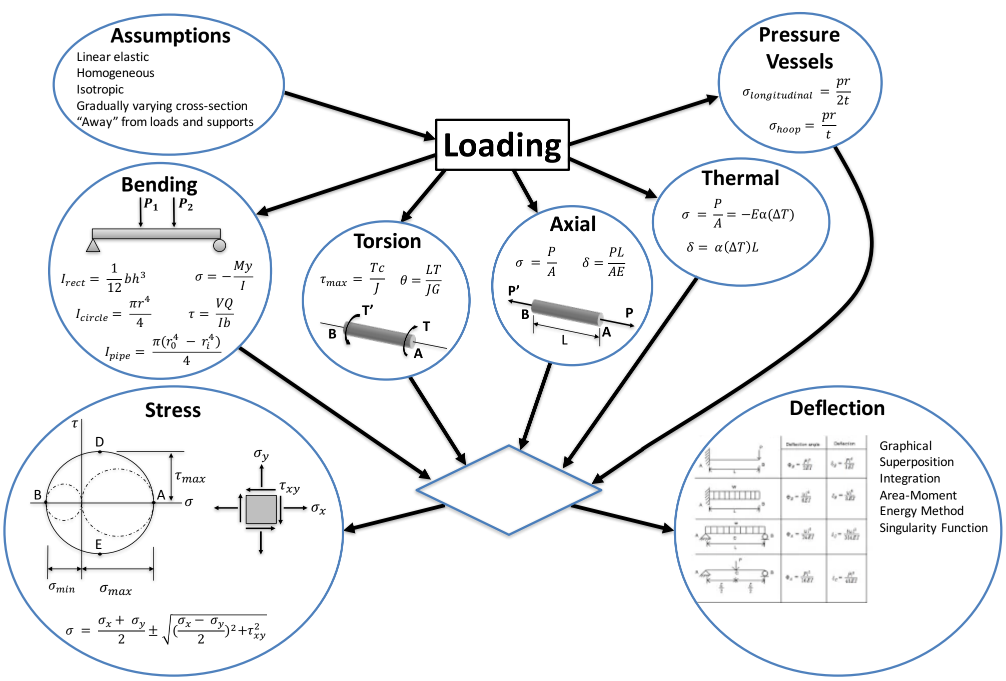
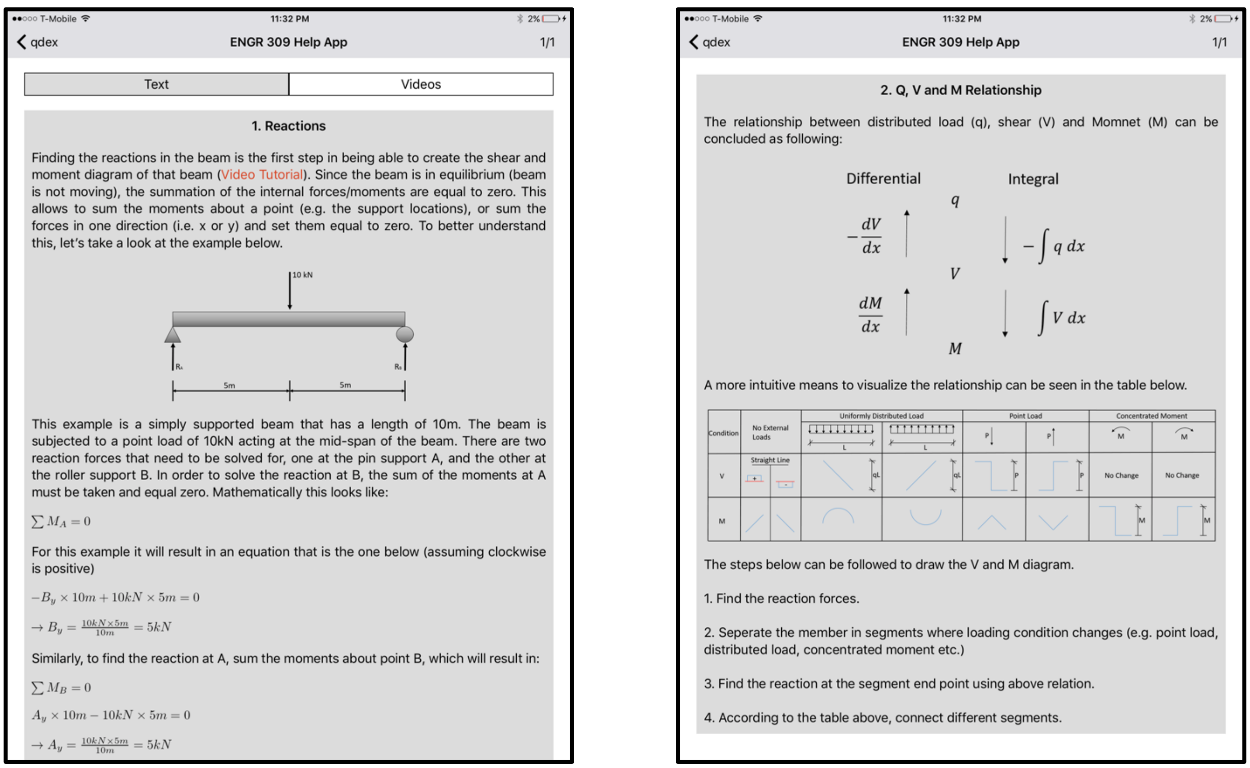


Figure 3. Main Flow of the Knowledge Apps - Common Concept Map [17]

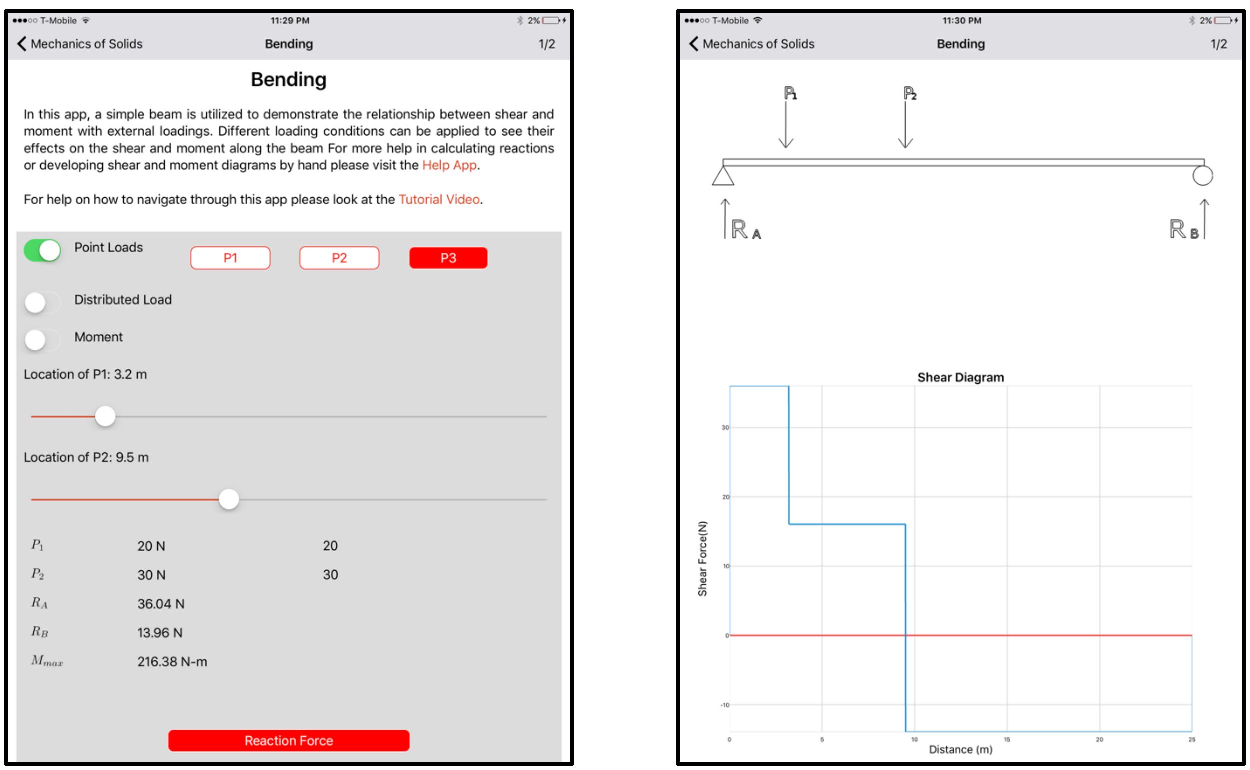
To make the course materials more accessible, an auxiliary app called *Help* is developed to provide lecture materials in the form of text and video. Fig. 4 shows materials in text form. This media does not require students to have internet access, allowing the materials to be the most accessible. The other form of media is recorded videos as described in the above Recorded Review Videos section. These videos are hosted on YouTube and directly accessible in the app. The advantage of having recorded videos is that students are able to view the lectures at their own pace. Both of these media offer students the opportunity to access lecture materials outside the class with the mobile device that they carry with them. This allows students to take the classroom anywhere, while also allowing instructor to conserve in-class time for other activities and topics to be covered. With the textbook prices going up exponentially every year, incorporating the materials in the *Help* app also provides an opportunity to make the learning materials more affordable for financially challenged students. The contents of the *Help* app are linked throughout the various knowledge apps to provide easy access to students when they are struggling with particular concepts.



a) *Help* App Interface b) Learning Materials – Q, V, M

Figure 4. *Help* App

Herein, the *Bending* app is used as an example to demonstrate many of the novel qualities of the developed mobile apps. The *Bending* app investigates support reactions and shear and bending moment in beams caused by external loads. Being able to correctly calculate reactions and develop shear and moment diagrams is an essential concept that must be mastered to do well in the Mechanics of Solids class and future engineering courses. One most requested item when being asked "what can we do to help improve your learning experience?" in an anonymous survey to students is to have more practice examples after delivering the theory. Although it is difficult to incorporate a large amount of examples in class, given the limited time of the semester, this app gives students the opportunity to create their own example problems while also getting immediate feedback on if their hand calculations are correct. Students are able to apply different loading scenarios to a simply supported beam as shown in Fig. 5b. Different loading types include point loads, concentrated moments, and a distributed load across the entire beam are available. Students can select multiple loads as well as their locations by using a slider to move the load along the length of the beam. A two-point loads case is used as example to demonstrate in Fig. 5. Having the ability to choose types and placements of loads allows students to be creative in the problems they set up for themselves. Diversity of problems that they can explore only strengthens their understanding of the concept of shear and bending moment diagrams. The ability to create their own diverse examples allows them to spend more time outside of the classroom to practice applying the knowledge learned in the classroom. Providing instant feedback on the correctness of the problem helps them gain confidence along the practice process. The *Bending* app allows instructors to use less time on creating examples, solutions for these examples, and spending class time going over examples, thus giving the instructor more in-class time to introduce and explain topics covered in the class.



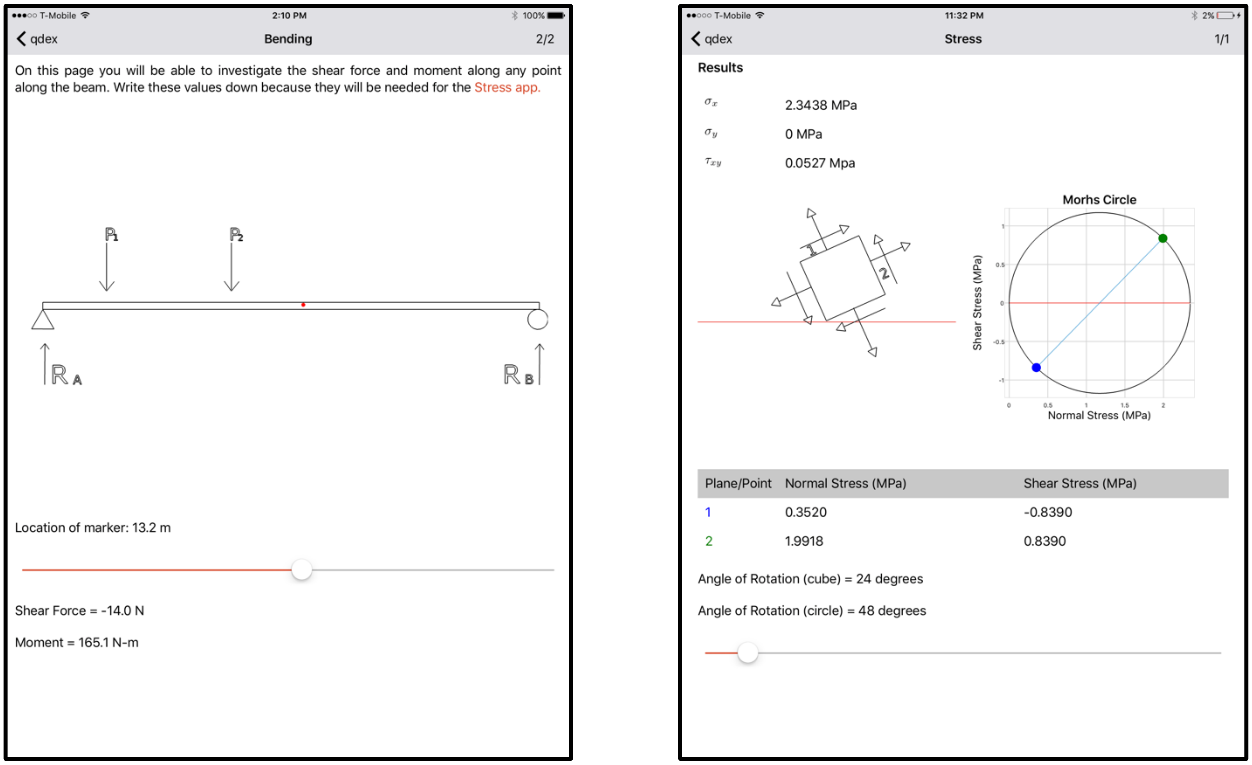
a) *Bending* App – Input

b) *Bending* App – Shear Diagram

Figure 5: Bending App

The various apps listed in Table 1 are designed to work together. For example, after checking their work on the shear and moment diagram, students can evaluate the shear and moment at any point along the beam through a slider on the second page of the *Bending* app as shown in Fig. 6a.

This information can be input to the *Stress* app to further investigate the stress and strain at the cross-section of the beam and better understand their relationship through a Mohr's Circle (Fig. 6b). When the students move the slider as shown in Fig. 6b, the corresponding rectangular element, points at Mohr's Circle, and their values will reflect the changes in real-time, providing an interactive and intuitive experience for students to better understand the relationship.



a) Shear & Moment along Beam b) Mohr's Circle

Figure 6: Information Continuity between Apps

Implementation and student success evaluation

The module of interactive educational knowledge apps was introduced to a Mechanics of Solids class in the Spring of 2017. A total of 32 students were enrolled and participated in the pilot study. Student's majors were a mix between Mechanical (16 students) and Civil Engineering (16 students). Pre- and post-surveys, developed in Qualtrics [18], were conducted to collect students' characteristics, and used as an indirect measurement to quantify the effectiveness of the developed knowledge apps. Among the 32 students, 28 students participated in the pre-survey and 24 participated in the post-survey. For the 28 students participated in the pre-survey, 20 (71%) are males, 6 (21%) are females and 2 (7%) prefer not to answer. 89% of them are a third-year student. Among these 28 students, 27 of them reported that they own a smartphone or tablet and the one didn't indicated s/he has plan to get one in the near future. Six questions were asked in both pre- and post-surveys to evaluate if the approaches improved students' understanding on the critical concepts in this course. To ensure the anonymity of the participant, unidentifiable identifiers were used in the surveys. Students were asked to provide the first 4 letters of the town they were born in and the last 4 number of their phone number. By matching these parameters, pre- and post-survey results were able to be compared without disclosing students' identity. Data from the pre- and post-surveys were analyzed using the Statistical Package for the Social Sciences (SPSS) [19]. The correct answer is assigned a 1, while the incorrect answer is assigned a 0. The total score is then added up and compared between the pre- and post-survey. The results from this indirect measurement from 11 students were concluded from the pre- and post-survey results and displayed in Tables 2 and 3. Only results from 11 students could be used because some students did not use the same unidentifiable identifiers for the pre- and post-surveys, which is an area to be emphasized in the future implementation. The results are very promising considering the mean score was raised from 2.3 to 3.7 between pre- and post-surveys, showing that the interactive knowledge apps had a positive effect on helping students understand concepts presented in the Mechanics of Solids class.

Table 2: Pre- and post-survey results

Measures	Mean	Std Deviation	Std Error Mean
Total pre-test score	2.30	1.252	0.396
Total post-test score	3.70	0.949	0.300

Table 3: Paired Samples Test

Measures	t	df	Sig. (2-tailed)
Total pre-test score – Total Pre-test Score	4.583	9	0.001

In addition to evaluate the students' knowledge competence before and after the intervention, the final grades of the students in Spring 2017 are compared to those from Fall 2014 to provide a direct performance comparison with and without using the intervention. In order to have direct comparison to the Spring 2017 class, material such as tests and quizzes, were directly adopted from the Fall 2014 class. The same instructor was teaching both semesters. The Fall 2014 class was chosen because of its similar class size, and the time between semesters would minimize the possibility of passing materials between students. The grade comparison between students in these two semesters is shown in Fig. 7, where the blue series is the final grades from the Fall 2014 class, and the orange series is final grades from students in the Spring 2017 class. Results show that the Spring 2017 class had more students with A and B as final grades, less C, D final grades, and the same number of F grades. Results indicate that using the developed strategies sways C students to the A and B range.

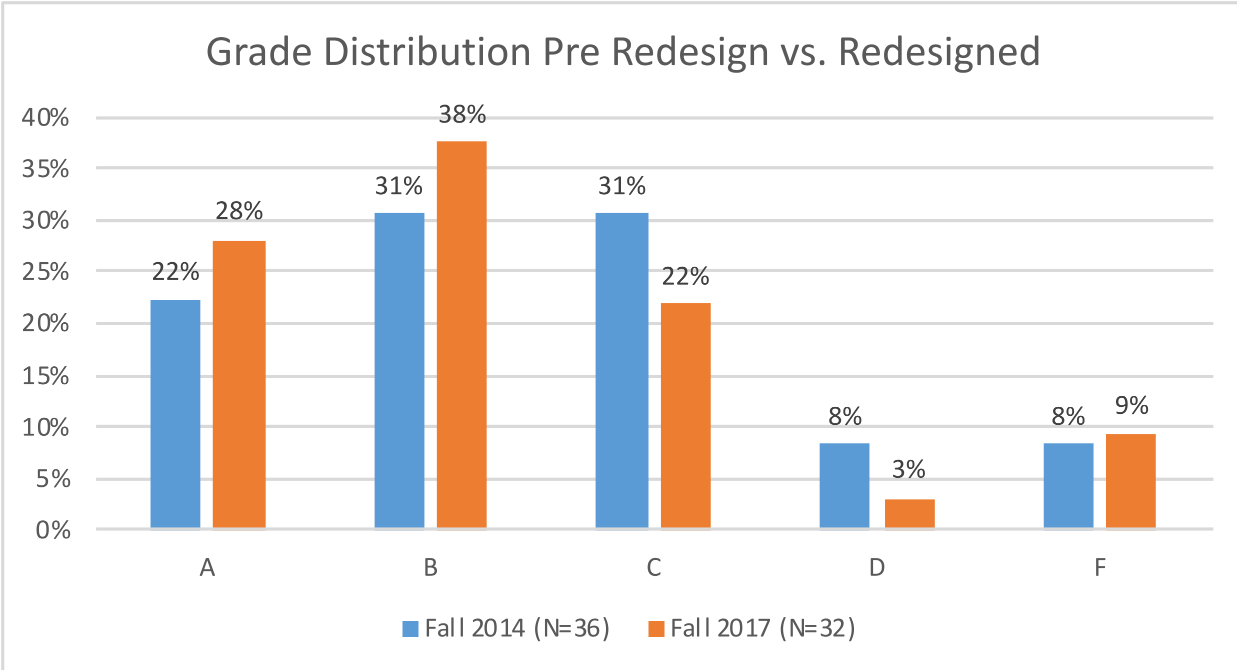


Figure 7: Grade Distribution Comparison

Students comments were also collected to gauge if the mobile learning experience was positively viewed by the participating students. Some comments from the students who participated include "It's a very good user-friendly app for students and I look forward to seeing its progress in the future" and "Keep developing the learning modules! They have served me very well and will only help future students succeed. I hope other professors/teachers can take note of this learning tool and incorporate similar methods into their learning environments." These comments solidify that the apps were beneficial for students, and that students enjoyed incorporating mobile devices into the learning experience for this course.

Conclusion and Future Work

With the advancement of mobile technologies, mobile learning has become available for delivering educational materials to students in all levels. Students have shown an attitude acceptability towards mobile learning and a desire to have mobile devices utilized in the classroom. Taking advantage of this opportunity to better serve the need of the next-generation learners in a more accessible way, a series of strategies designed upon mobile technologies are developed and implemented in the low success rate Mechanics of Solids course at SFSU. These strategies include recorded review videos to help students review prerequisite concepts, a series of interactive mobile learning apps to help students consolidate and practice gained knowledge, and virtual office hours to provide timely and easily accessible guidance and feedback to students.

To assess the effect of the developed strategies on students' performance, two metrics were used. A direct comparison of students' grades from the Spring 2017 to Fall 2014 showed that the strategies had an effect in lowering the number of students who earned a final grade of a C's and D's, while raising the number of students who earned A's and B's. An indirect measurement through pre- and post-surveys before and after the intervention was also employed to further evaluate the effectiveness of the strategies. The surveys consisted of questions that tested students on their knowledge of concepts covered in the course. Results from this indirect measurement demonstrated that the mobile module had a positive effect on students understanding of the concepts in the course.

The study shows potential of using these strategies in improving student learning, however, the sample size of the students was relatively small to provide a conclusive result. Continue implementation in consequent semesters is planned to obtain a larger sample size and confirm the effectiveness of the strategies. Other future work includes analyzing usage statistics of the mobile knowledge apps to determine what components make the apps successful. These usage statistics include how long students are using the apps, how many times they open the apps, how many times the apps have been downloaded, and what features (buttons, graphs, and sliders) students used the most.

Acknowledgement

The authors would like to thank the funding from The IDEA Center, the California State University Course Redesign with Technology program, SFSU Affordable Learning Solutions Initiative, and SFSU College of Science and Engineering and the School of Engineering to support this project. The authors would also like to acknowledge Quanser Inc. and Academic Technology at SFSU for their supports in developing the materials mentioned in this paper.

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