

SecPro app as an educational tool for teaching engineering mechanics

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Abstract—Incorporation of educational apps into classroom curriculum including gamification, collaboration, self-learning and assessment apps is a major trend in engineering education. Educational applications either in desktop or mobile devices enable students to learn in a modern context when they are used as teaching tools in various engineering disciplines. *SecPro* is an educational app that is developed as a self-learning and self-assessment tool for engineering students. This app provides a tool for studying the section properties concept which is primary knowledge required in engineering mechanics topics such as Statics, Mechanics of Materials and Design of Steel Structures. It enables students to participate in self-learning and post class activities. Part of these activities include making various sections by combining basic elements, following step-by-step calculations and trying to optimize section properties through game-based simulations. The efficiency of this app-based educational technology in active learning and adaptive evaluation of students in Mechanics of Materials is discussed in this paper. The effect of using such educational app on the performance of students was experimentally measured by comparing the performance of students who use this app with those who use traditional methods. As an experiment, this app was integrated into assignments of a large section undergraduate course with a diverse student population. The app is offered to students as an optional tool; the performance of students is monitored quarterly during the semester and in the final common exam. The results of this case study showed that the students applied and learned skills related to section properties successfully and their attitudes towards engineering mechanics improved.

Keywords—*Educational app; Engineering mechanics; Adaptive learning; large section; case study*

1. Introduction

A recent trend in education and more specifically engineering education is incorporating educational apps into classroom curriculum (Kickmeier-Rust et al. 2015, Blair et al. 2015, Mouza and Barrett-Greenly 2015). Educational apps are available for several different platforms e.g. desktop computers (with Linux, Mac OS, and Windows OS), mobile devices (with Android, iOS and Windows OS) and web applications. The shortened term “*App*” is sometimes used to refer to applications for mobile devices such as smart phones and tablets; the shortened form matching their typically smaller scope compared to applications on desktop computers. However, mobile devices are becoming more powerful and operating systems are getting more uniform across desktop and mobile devices; thus, “*educational app*” is referred to any computer program designed to help teachers and students study the subject of a course through collaboration, practicing, self-learning and assessment.

Several educational apps have been developed and incorporated into engineering curriculum (Flori et al. 1996, Oglesby et al. 1998, Philpot 2000, Philpot and Hall 2006). Some educational apps for the engineering course are typically presented as tutorials, worksheets, or basic analysis packages while some others provide more interactive features with instant feedback and hints. This paper is aimed at investigating the efficiency of an educational app called “*SecPro*” in Mechanics of Materials curriculum. The benefits of using a typical interactive educational app compared to the textbook as a traditional method are:

- Provides solution as a benchmark for self-studying
- Helps student to visualize various problems with different geometries
- Gives an opportunity to the student to grasp the fundamental concepts by repeating a problem with different parameters
- It is available out of regular class time when students do not have access to the instructor or teaching assistant
- Encourage students to attempt more problems and see what happens if they change problem parameters.

2. Section properties app for engineering mechanics

Engineering mechanics courses including Statics, Dynamics and Mechanics of Materials are core courses for many engineering majors such as civil, mechanical, aerospace, architectural, and metallurgical engineering. These courses are also part of programs such as environmental, manufacturing, nuclear, and petroleum engineering.

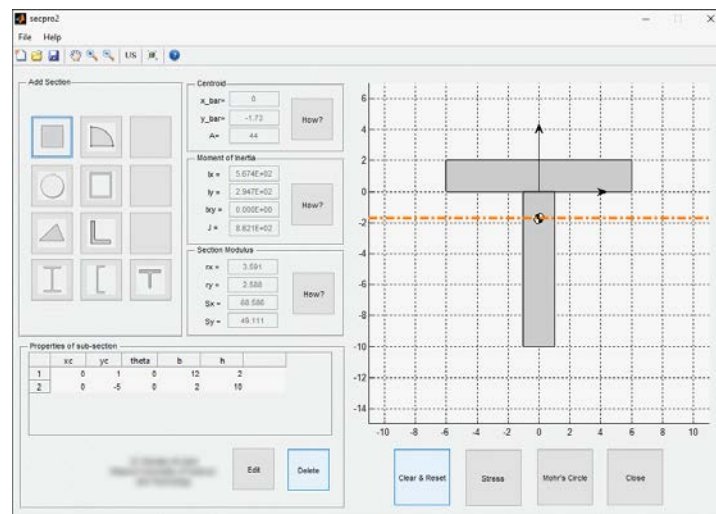


Fig. 1. Screenshot of the Secpro app

The engineering mechanics courses introduce students to the analysis and design of basic structural components of engineering machines and structures such as airplane, automobile, spacecraft, bridge, power plant, residential or commercial building etc. The engineering mechanic courses are aimed at developing the student’s ability in analyzing the equilibrium of loads in stationary or moving objects and analyzing the effects of forces on solid bodies (stresses and strains).

Among the important concepts in engineering mechanics, learning to determine section properties (e.g. centroid, moment of area and moment of inertia) is an important one that is primarily discussed abstractly in the Statics. This basic concept has practical applications in Mechanics of Materials which is a course that is taken during the sophomore or junior year after students complete different pre-requisite courses such as Statics and calculus. Based on author experiences, students often struggle with recalling the concepts of section properties and using it to solve problems in Mechanics of Materials. Reviewing the section properties concept in Mechanics of Materials often takes significant lecture time to cover adequately. An educational app called “*SecPro*” was developed by the author to provide students with a self-learning and automated assessment educational app to fill the gap with respect to section properties.

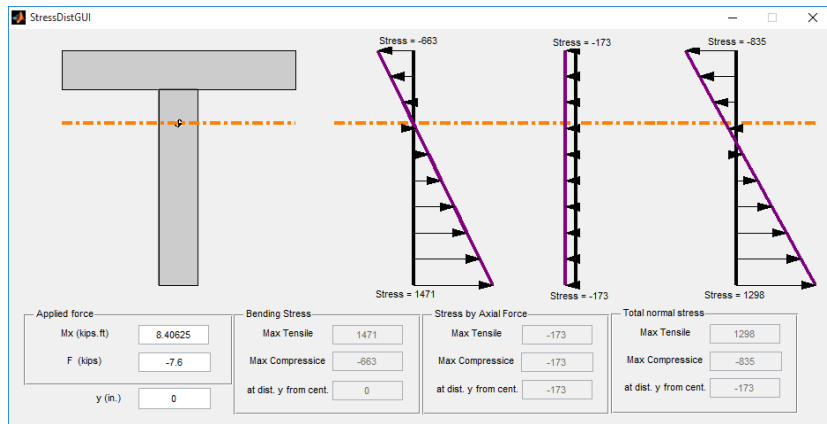


Fig. 2. Stress analysis using the Secpro app

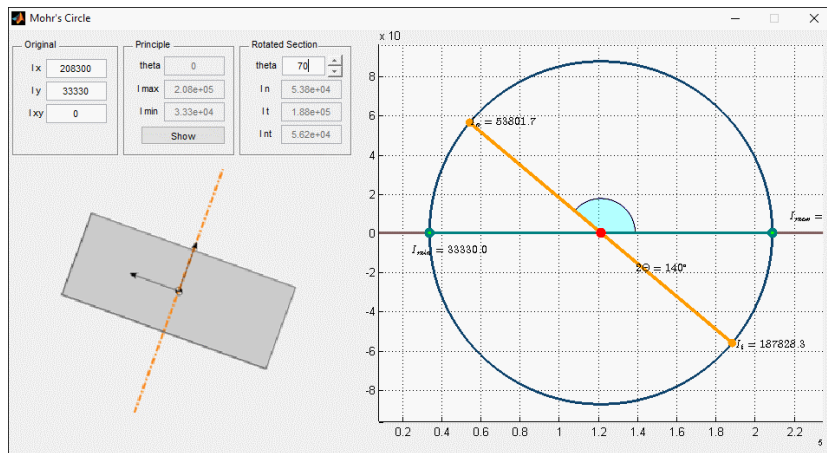


Fig. 3. Rotated section and the Mohr circle in the Secpro app

SecPro is an educational tool that is primarily developed to help students understand and solve problems related to section properties. The app is compiled as a stand-alone multi-platform software which runs under Windows base PCs and tablets as well as Mac systems. A user manual, installation guide and several solved problems were prepared as explanatory and supplementary documents. In addition, a few instructional videos are prepared which are available in the author's YouTube channel (AISC 2005).

The SecPro app is versatile, graphic, informative, and easy to use. A screenshot of the app is shown in Fig. 1. The app enables making various sections by combining simple subsections or selecting sections from predefined AISC standard steel shapes (Libre 2016). Stress analysis of the section subjected to axial force and bending moment can be performed with the app. A typical example of stress analysis is shown in Fig. 2. Other important features of the app are:

- Calculating various section properties including centroid, moment of inertia about two perpendicular axes, polar moment of inertia, section modulus and radius of gyration
- Rotating each subsection or the entire section
- Compatible with both English and SI units with a button to switch the units
- Easy section editing by dragging and dropping subsections with mouse
- Mohr circle analysis for determining section properties of a rotated section. Fig. 3. shows the Mohr's circle analysis for a rotated section.

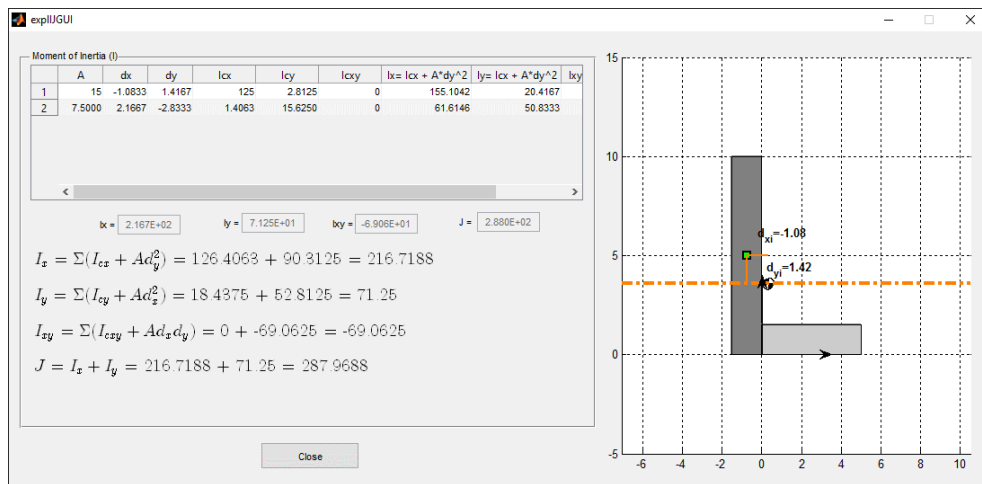


Fig. 4. A sample detailed calculation

In a traditional teaching format, instructors assign homework and expect students to work enough on the homework to grasp the fundamentals. However, students sometime struggle with homework due to uncertainties about their solution. One important feature of the app is the “How” button which provides details on how various section property parameters are calculated. This feature not only provides students with the correct answer but also provides the detailed solution which is very helpful as a benchmark to validate their methods. To supplement the student's educational development, the self-study potential offered by the app would seem to be a suitable tool for filling the gap between the material presented in lectures and the understanding and skills expected in homework and exams.

3. Research approach

3.1 Experimental procedure

The SecPro educational app was offered to students of Mechanics of Materials in fall 2015 and spring 2016. Students were allowed to use the app for studying and solving problems or use the traditional studying method. The efficiency of the SecPro app in Mechanics of Materials is examined experimentally by comparing performance of the test group with reference group of

students. Test group is considered as a group of students who used the app for solving more than four problems. Reference group is referred to the rest of students in the class.

3.2 Quantitative assessments

The performance of students is monitored during the semester through regular summative assessments. The assessment items used in this study include: Final exam, four midterm exams, 10 assignments and one quiz. There was not any bonus point associated with using the app to avoid unfair discrepancy in grading practice between various students.

Student activities including total time spent for studying and solving section property problems, total problems and total subsections investigated by each student were recorded within the app. Based on collected information, 64 students solved about 890 problems and spent over 8000 minutes to study the section properties within the investigation period. Table I. shows the number of students in test and reference groups as well as the number of problems and the total time that students spent for solving problems.

TABLE I. SUMMARY OF SECPRO APP USAGE IN FALL2015 AND SPRING 2016

Semester	Number of students			Time (min) ^a	Number of problems	Number of sub-sections ^b	Average time ^c (min)
	Total	Test group	Reference group				
Fall 2016	120	21	99	2406	322	642	7.5
Spring 2016	134	43	91	5682	567	1351	10
All semesters	254	64	190	8088	889	1993	8.7

^a. The total time that students used the app for studying and solving problems

^b. Total number of subsections examined by students

^c. The average time spent for solving each problem

3.3 Uncertainties in analysis

It should be noted that the student activities were collected only if the device was connected to the internet while students were working with the app. Therefore, the numbers in Table I are representing the minimum student activity and there is possibly uncollected data. Another source of uncertainty in this experiment is the app sharing. Some students study together or share the same device with the same user name for studying. In this case, the activities were counted for the logged in user. Avoiding these sources of uncertainty is almost impossible. However, the effect seems to be negligible.

4. Results and discussion

4.1 Effect of using the app within the test group

The number of problems solved using the educational app by each student in the test group and the student score (exams, assignments and quiz) is examined to evaluate the effect of using the app on improving the knowledge of students with respect to section properties. The left chart on Fig. 5 shows the number of subsections versus students score. Even though there are high

variations, a positive trend is observed. The more the students used the educational section properties app, the higher scores they earned.

It should be noted that there are many topics discussed in Mechanics of Materials and just part of that is directly related to calculating section properties. To improve accuracy of analysis, the questions in the exams, assignments and quiz that are directly related to the calculation of section properties are analyzed separately. Results of such analysis is depicted in the right chart of Fig. 5. The slope of trend line is 72% higher in this case compared to the case where all grading items were considered in the analysis; showing higher impact of using the SecPro app on student's ability to solve questions related to section properties.

The same trend was observed by analyzing the student score versus the time devoted for studying with the app or the number of problems solved by each student. Solving more problems and studying more with the app resulted in the higher grade. The results of such analysis are not presented for the sake of brevity. The experiment conducted shows positive effect of using the SecPro on student's performance specifically for the grading items that are directly related to the section properties.

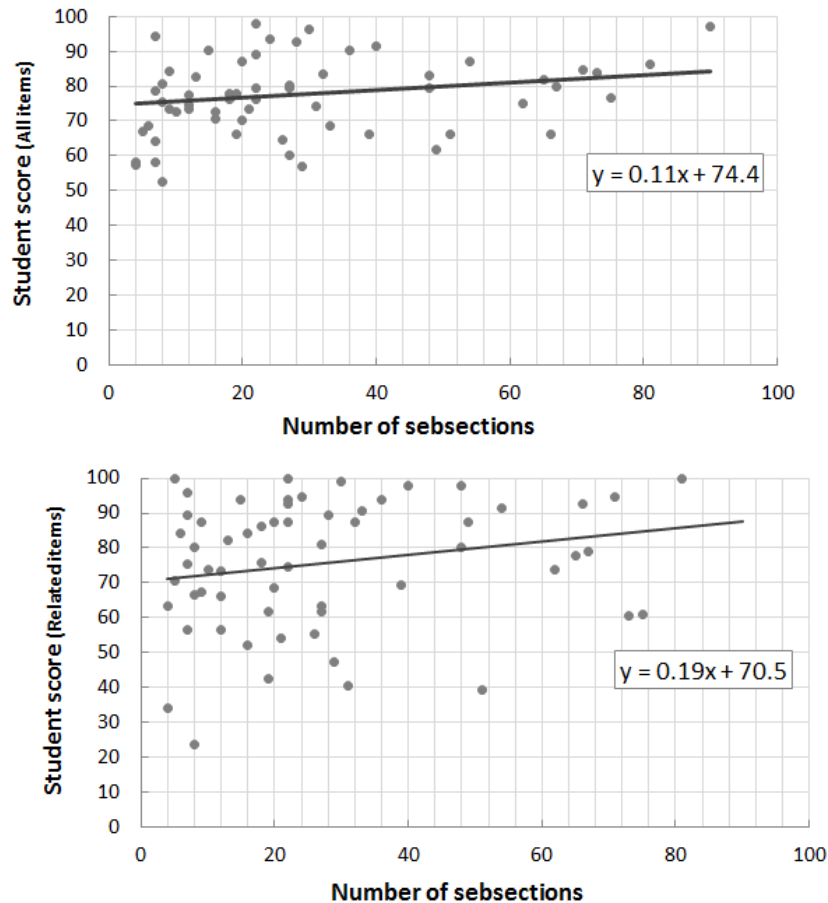


Fig. 5. Correlation between student scores and number of subsections examined by students in test group

4.2 Test group versus reference group

In the second part of this experiment, the performance of the test group who chose the app for studying the section properties is compared to the performance of students in the reference group who chose the traditional learning method. Students in both groups were assessed by the same items several times during the semester.

Fig. 6. compares the students performance metrics in various assessment items during the spring semester. The radar graph shown in this figure is used for displaying multivariate assessment items in the form of a two-dimensional chart. Each axis represents one assessment item.

Students in both the test group and reference group got almost the same grade for exam 1 and the first half of assignments (1 through 5) which are less related to section properties. On the other hand, the test group outperformed in exam 2, exam 3 and the second half of assignments; there are more topics related to the section properties in those assessment items. It shows the SecPro educational app has helped students in understanding the concepts related to this topic.

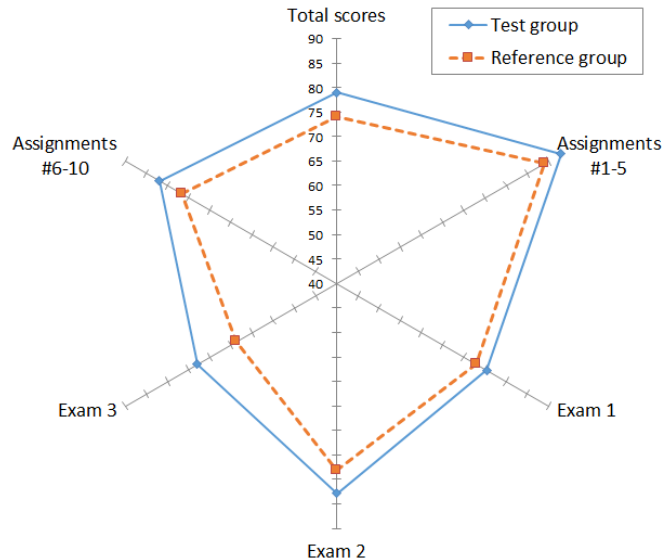


Fig. 6. Performance of test group and reference group in Spring 2016

The area inside the radar chart is another performance metric that could be used for quantifying students' knowledge. The higher the area inside a radar chart shows a better performance and grasp of the concepts by students. The area within the radar chart for the test group and reference group are 12,760 and 11,195, respectively. The test group showed 14% better performance in this metric.

Another observation was the performance of the test group and reference group in the exams taken during the semester. As shown in Fig. 7. the test group and reference group scored an average of 75 and 73 in the first exam, respectively. The first exam covers topics that are not related to section properties; both groups scored almost the same in that exam. The difference between the two investigated groups in the first exam is 2 points out of 100 points which is negligible. However, the difference between average score of the test group and the reference

group were 5 and 9 points in exam 2 and 3, respectively. These two exams are mostly covering the topics in which the properties of sections should be calculated and used. The results show that using the educational app for studying resulted in higher average scores over time compared to the traditional method of studying the textbook. The test group showed increasingly better performance over time, specifically for the topics related to section properties.

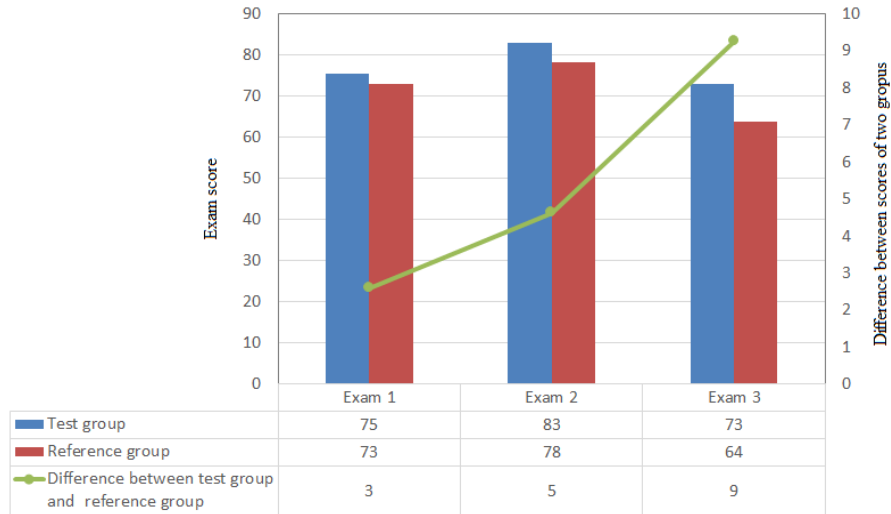


Fig. 7. A sample detailed calculation

5 Concluding remarks

This paper has given an overview of the SecPro app. The purpose of developing this educational app was to serve students who are taking engineering mechanics courses. The efficiency of this app was experimentally evaluated in a Mechanics of Materials course during fall 2015 and spring 2016 semesters. In the quantitative analysis, the test group and the reference group differed significantly on the assessment items related to section properties. Despite the fact that section properties is a topic that is mainly presented and discussed in Statics, a prerequisite course for Mechanics of Materials, the SecPro app helped students to review the section properties concept and enabled them to improve their performance in the related topics in Mechanics of Materials.

The result of this experiment has motivated the author toward sharing the developed app with other instructors of engineering mechanics across the country and around the world. The author has developed the app for non-profit purposes and the app is available for free to all students. The SecPro app has proven to be a valuable addition to the traditional textbooks in Mechanics of Materials courses. The app was conceived as a versatile tool to bridge the gap between the abstract section properties topics presented in Statics and their applications in Mechanics of Materials.

The feedback received from students as well as the results of the current experiment encourage the author to develop other educational apps to cover other topics in engineering mechanics in general and Mechanics of Materials in particular. A web based app that does not require installation and could be reached from any device seems to be a convenient option.

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References

- American Institute for Steel Construction, (2005). Specification for structural steel building. Chicago, Illinois, USA
- Blair, K.P., Pfaffman, J. , Cutumisu, M. , Hallinen, N., Schwartz, D. (2015). "Testing the effectiveness of iPad math game: Lessons learned from running a multi-classroom study," Conference on Human Factors in Computing Systems - Proceedings, 18, pp. 727-734.
- Flori, R. E., Koen, M.A., Oglesby, D.B. (1996). "Basic Engineering Software for Teaching (BEST) Dynamics," Journal of Engineering Education.
- Kickmeier-Rust, M.D., Hillemann, E.C., Albert, D. (2015). "Gamification and smart feedback: Experiences with a primary school level math app," Gamification: Concepts, Methodologies, Tools, and Applications, 2-4, pp. 970-982.
- Libre, N.A., "Instructional videos for the SecPro App", <<https://www.youtube.com/playlist?list=PLR7woIxuVhpEjvtRdTResAqgzK1ESG0S>> (Mar 18, 2016)
- Mouza, C., Barrett-Greenly, T. (2015). "Bridging the app gap: An examination of a professional development initiative on mobile learning in urban schools," Computers and Education, 88, pp. 1-14.
- Oglesby, D. B., Carney, E.R., Prissofsky, M., Crites, D. (1998). "Statics On-Line: A Project Review", ASEE Annual Conference Proceedings, Seattle, WA
- Philpot, T.A., (2000). "MDSolids: Software to Bridge the Gap Between Lectures and Homework in Mechanics of Materials," International Journal of Engineering Education, 16(4)
- Philpot, T.A., Hall, R., (2006). "Animated Instructional Software for Mechanics of Materials: Implementation and Assessment", Computer Applications in Engineering Education 14 (1), pp 31-43

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Nicolas Ali Libre, PhD, is an assistant teaching professor of Civil Engineering at Missouri University of Science and Technology. He received his BS (2001), MS (2003) and PhD (2009) in civil engineering with emphasis in structural engineering, from University of Tehran, Iran. His research interests and experiences are in the field of computational mechanics, cement-based composite materials and teaching innovations.

Given his multidisciplinary background, he was appointed as the director of research in the Construction Materials Institute (2011-2013) at the University of Tehran. In April 2013 he

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