Final Report

Evaluation of Section Properties App for Mechanics of Materials

Educational research mini-grant project

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Summary

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. An educational app is developed in Missouri University of Science and Technology as a self-learning and self-assessment tool for engineering students. This app provides a tool for studying the section properties concept which is a primary knowledge required in engineering mechanics topics such as statics, mechanics of materials and Design of structures. It enables students to participate in self-learning and post class activities. Part of these activities include making various sections by combining simple 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 performance of students was experimentally measured by comparing 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 and performance of students is monitored quarterly during 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.

1 Purpose of project

The purpose of this project is to evaluate efficiency of an app-based educational technology in active learning of students in mechanics of materials. The efficiency of such active learning technology on facilitating learning of section properties is investigated through an experimental program in spring 2015 and fall 2016. A literature review of using app as educational tools as well as a brief introduction of the developed app is presented in Chapter 2. Research methodology and the experimental program are described Chapter 3. Results are presented and discussed in chapter 4. The report is concluded in Chapter 5 by summarizing the results and discussing about the plans for further Dissemination.

2 Introduction

2.1 Background

A recent trend in education in general and in engineering education in particular is incorporating educational apps into classroom curriculum [1-3]. 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 "*App*" has 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 [4-6]. 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 feedbacks and hints. This paper is aimed at investigating the efficiency of an educational app called "*SecPro*" in mechanics of materials curriculum. The benefit of using a typical interactive educational app compared to the text book as a traditional method are:

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

2.2 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.

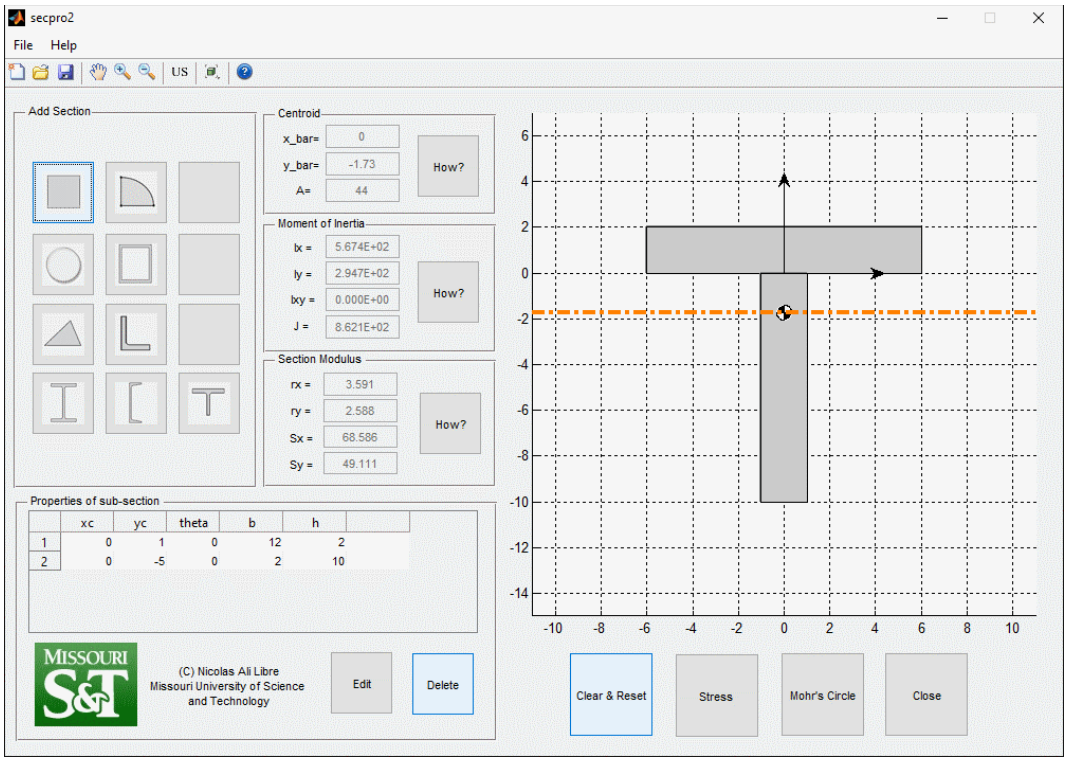

Figure 1. Screen shot of the Secpro app

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 and 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 important one that is primarily discussed in the statics in an abstract way. This basic concept has practical applications in mechanics of materials which is a course that is taken during the sophomore or junior years after students complete different pre-requisite courses such as statics and calculus.

Based on author experiences, student 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 take 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 out the gap with respect to section properties.

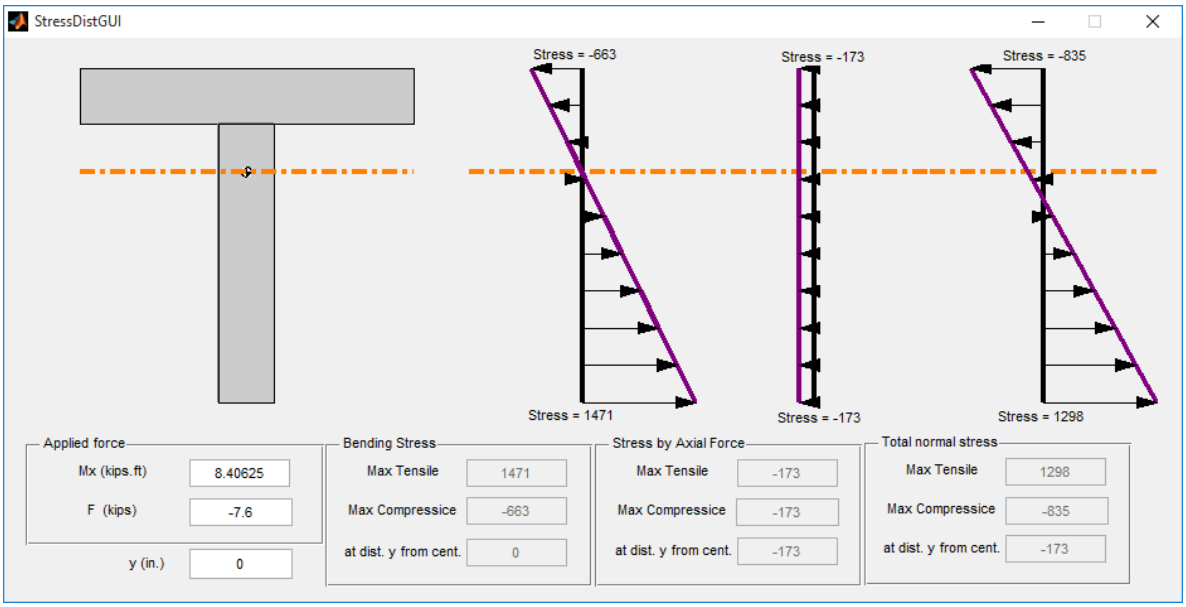

Figure 2. Stress analysis using the Secpro app

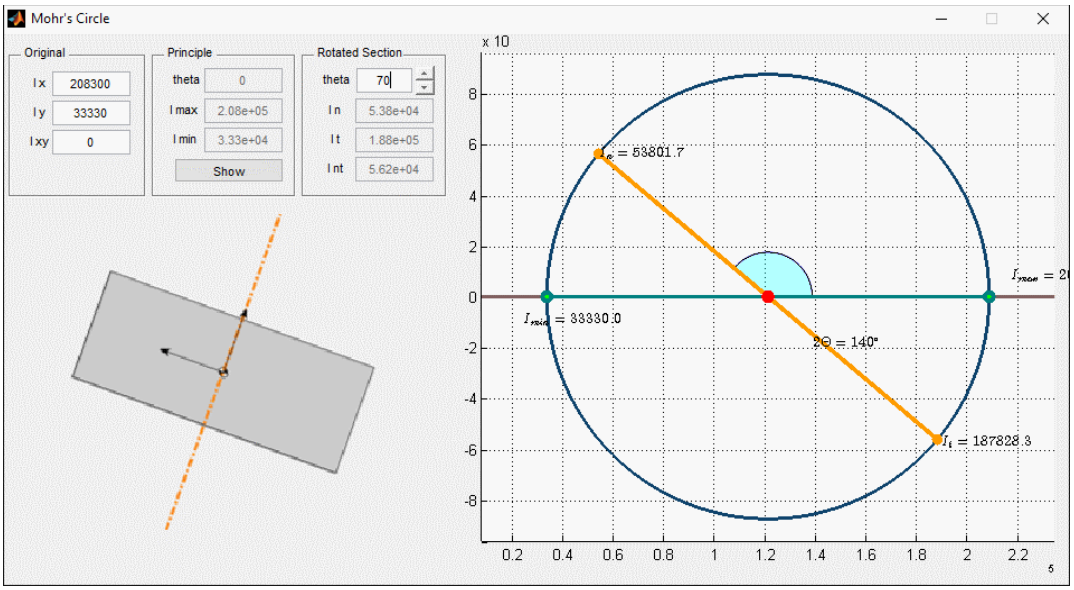

Figure 2. Rotated section and the Mohr circle in the Secpro app

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, few instructional videos are prepared which are available in the author's YouTube channel [7].

The SecPro app is versatile, graphic, informative, and easy to use. A screen shot of the app is shown in Figure 1. The app enables making various sections by combining simple subsections or selecting sections from predefined AISC standard steel shapes [8]. 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 Figure 2.

Other important features of the app are:

- Calculating various section properties including centroid, moment of inertia about two perpendicular axis, 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. Figure 3. shows the Mohr's circle analysis for a rotated section.

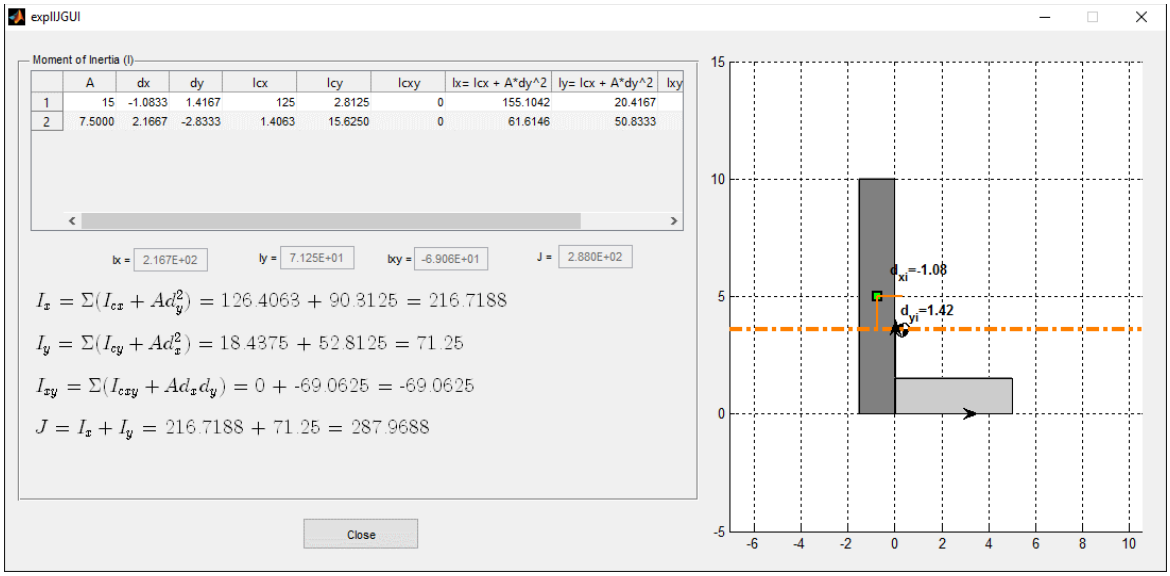

Figure 2. A sample detailed calculation

In a traditional teaching format, instructors assign several homework and expect student to work enough on the homework to grasp the fundamentals. However, students sometime struggle with homework with uncertainties about their solution. One important feature of the app is the "How" buttons which provide 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.

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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 and methodology

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

3.2 Quantitative assessments

The performance of students is monitored during 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 Uncertainties in analysis of students in test and reference groups as well as the number of problems and the total time that student spent for solving problems.

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

Semester	*Total number of students*	*Number of students in test group*	*Number of students in reference group*	*Time (min)* [a]	*Number of problems*	*Number of sub-sections* [b]	*Average time* [c] *(min)*
Fall 2015	120	21	99	2406	322	642	7.5
Spring 2016	134	43	91	5682	567	1351	10
Total	254	64	190	8088	889	1993	8.7

a. The total time that student 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

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 1 are representing the minimum student activities and there are 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 source of uncertainties 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 got.

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 Figure 5. The slop 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.

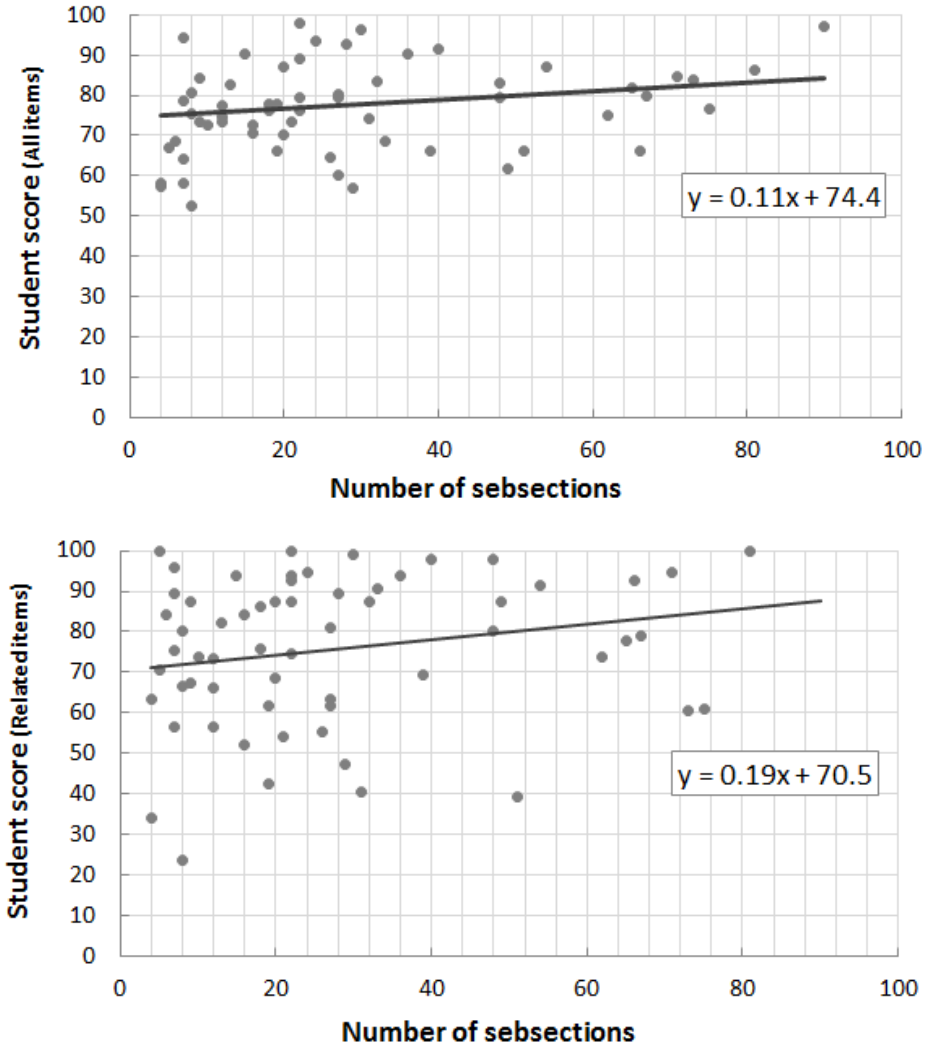

Figure 5. Correlation between student scores and number of subsections examined by students in test group

4.2 Test group versus reference group

In the second part of this experiment, the performance of 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 group were assessed by the same items several times during semester and by the end of semester.

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

Students in both 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 the 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 student in understanding the concepts related to this topic.

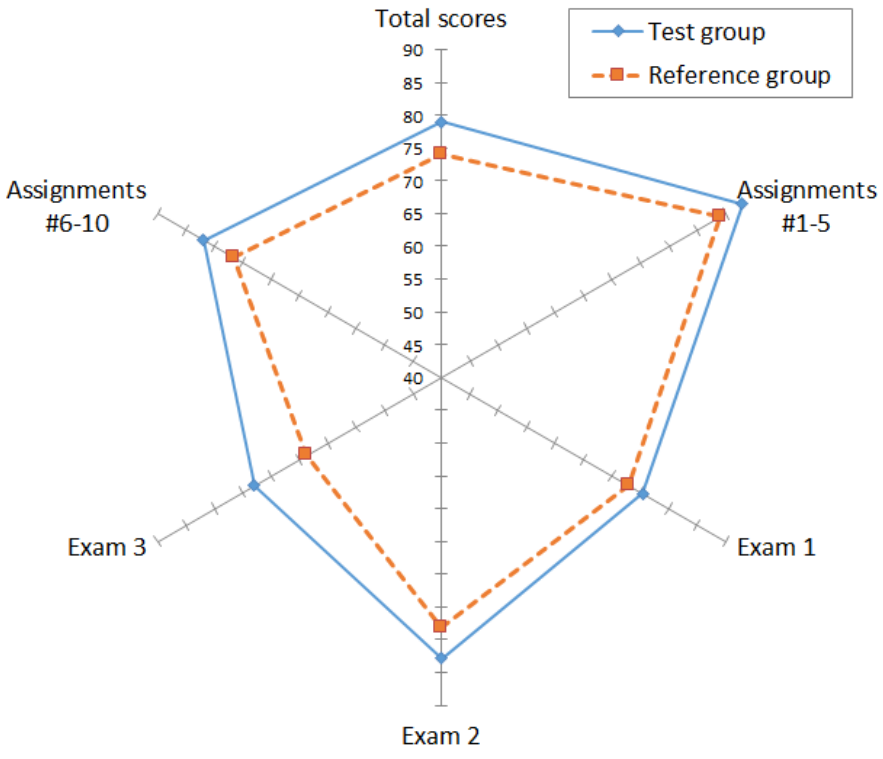

Figure 6. Performance of test group and refernce group in

5 Conclusion

The efficiency of the SecPro app was experimentally evaluated in mechanics of materials course in 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 the section property is a topic that is mainly presented and discussed in the 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 SecPro app has proven to be a valuable addition to the traditional text books 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 form 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 devices.

The preliminary results of this research has been presented in the Teaching and Learning Technology conference. The final results will be presented in the annual conference of American Society of Engineering Education (ASEE) in June 2017.

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