Development of "Engineering Economics Career" Mobile App

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Abstract: This paper presents the cross-platform mobile app development process of a newly developed app for an Engineering Economics course. The new mobile app was designed based on the formative assessment of our apps that were developed and used in classroom settings for the past two years. The newly designed app is named, 'Engineering Economics Career,' simulates the growth of an engineering economist in a virtual company. The app integrates various components including e-book, calculator, reference tables, conceptual questions and practical problems. The E-book is a summary of the key concepts of Engineering Economics. The calculator provides functions to solve basic engineering economics problems with formulas. The tables allow the users to compute discrete compound interest factors. The main interface is a Career game. Through this game, a user will encounter challenges with conceptual problems and also calculation problems in order to make a few financial decisions. As users successfully go through challenges, they will progress through five stages: Intern, Engineer, Senior Engineer, Head of Engineering and Chief Operation Officer. Each stage will have a selected number of conceptual and calculation problems. While a user can accept all stages, one must finish all problems in each stage in order to be promoted to the next stage by earning some points. A user can work on a problem repeatedly in order to gain more points, which will indicate how much effort a user spends in each stage for their learning. Sets of problems range from simple questions on time values of money to more complex concepts, such as Sensitivity Analysis, Monte Carlo Simulation, and Supply Demand Equilibrium. From the problem interface, users may access topics of their interest in the E-book and use the calculator and interest tables to help themselves. This app has been developed for both Apple iOS and Google Android platforms, and they have been released in the Google Play and Apple App Store. The cross-platform app development allows easy deployment to multiple mobile platforms. This app is intended to give students more opportunity to learn and practice concepts of Engineering Economics whenever and where they want using their mobile devices.

1. Introduction

Engineering Economics concepts are not intuitively clear for engineering students since they are required to understand the concept of giving different values to the same amount of money if considered at different times. Research indicates that students have a difficulty in developing the deep-level understanding required to achieve insight into the principles and rules underlying specific facts or results[1]. To address the difficulties, instructors have been pursuing different teaching aids such as project-based learning[2] and simulation and multimedia to help convey these concepts[3]. The instructor reports that very frequently students confounded time value of money with inflation.

Multimedia is defined as 'presenting both words (e.g., spoken or printed text) and pictures (e.g., illustrations, photos, animation, or video).' The theory of multimedia learning suggests that 'people can learn more deeply from words and pictures than from words alone[4]. Mayer's cognitive theory of multimedia learning, Sweller's cognitive load theory and Schnotz's integrative model of text and picture comprehension focus on the process by which people build mental representations from words and pictures. Our design of the mobile apps followed the instructional design principles derived from the cognitive load theories. Gamification - the use of game thinking and game mechanics in non-game contexts to engage users in solving problems – techniques have been advocated to improve user engagement in a mobile learning environment[5]. Typical game components are Points, Badges and Leaderboard (PBL). Sharing and collaboration are also important to viral dissemination of games.

Since personal computers became available in homes and schools, development in educational technology has progressed at an accelerated pace[6]. In this paper, we focus on mobile apps for multimedia learning. A small application that runs on a smart mobile device such as iPad and iPhone is called an app. Different app development tools are needed for different operating systems (platforms). For example, Apple apps are typically developed within the X-code environment in Objective-C programming language and can be deployed to iPhone, iPod Touch or iPad. Another example, Android apps, are typically developed in Java language and deployed to Android devices. A growing trend in recent cross-platform app development is to use HTML5 and JavaScript, which are utilized in this version of app development to obtain a uniform interface across different mobile platforms. The major benefit is 'develop once, deploy everywhere', which means the same code can be deployed to different platforms with little efforts.

The rest of the paper is organized as follows. Section 2 introduces the history and technology background. Section 3 explains our published mobile app, "Engineering Economics Career". Section 4 concludes the paper and suggests future work.

2. History and Technology Background

In Summer 2012, the authors developed the first version of the Engineering Economics mobile app to reinforce and improve the understanding of fundamental principles of Engineering Economics through the use of the smart phone apps outside the classroom[7]. The topics include time value of money, cash flow modeling, applications of interest rates, decision making, effects

of taxes and depreciation. The user interface was a traditional Android or iOS App with five tabs: E-book, Calculator, Reference Table, Conceptual Problems and Practice Problems[7]. It was incorporated into the Engineering Economics course in two long semesters (Fall 2012 and Spring 2013).

After one year's formative assessment with undergraduate engineering students, the app was renamed as "Engineering Economics Jeopardy!"[8]. The user interface evolved into an educational game style, which was one of desired features by students. The app incorporates all the previous components including E-book, calculator, reference tables, conceptual problems and practical problems, from the previous version but present them in a different and livelier fashion. The updated app was much better embraced by the students in the second years (Fall 2013 and Spring 2014). However, from the developer point of view, the maintenance of the app for different mobile platforms was not easy.

After two years' formative assessment, the app is rewritten as "Engineering Economics Career" game with HTML5 and JavaScript for cross-platform development. Currently it is being distributed through Apple App Store as an iOS app and Google Play Store as an Android app. It will be easily deployed to many other devices such as Windows and Blackberry devices.

The development of the "Engineering Economics Career" app utilized a number of free or open source mobile web technologies.

- HTML5: HTML (HyperText Markup Lanaguge) is the language for all the websites. HTML5 is the latest evolving standard for HTML. It has been supported in all the major web browsers, to different extents.
- CSS3: CSS (Cascading Style Sheet) is used to control the style and layout of webpages. This helps to split the appearance from the content in web pages. CSS3 is the latest standard for CSS.
- JavaScript: JavaScript is the scripting language of the web. It adds interaction and animation to websites. It is playing a more and more important role in modern web browsers. It works well with HTML5 in all the major web browsers
- jQuery[9]: jQuery is a fast JavaScript library. It makes HTML document handling much simpler compared to plain JavaScript. Many plug-ins and extension have been written for jQuery to extend its functionalities. There are several competing JavaScript libraries to jQuery though.
- jQuery Mobile[10]: jQuery Mobile is a unified, HTML5-based user interface system for all popular device platforms. It is built on the jQuery foundation. It considers the specific requirements from the mobile platforms, considering the multi-touch user interface in particular. JQueryMobile has also been built into popular web design software such as Adobe DreamWeaver.
- jqPlot[11]: jqPlot is a plotting and charting plugin for jQuery. With jqPlot, we can easily plot all kinds of charts including line, bar and pie charts. There are many competing JavaScript charting libraries. We utilized jqPlot to plot the curves and histograms in the problems description.
- PhoneGap[12]: PhoneGap is a free and open source framework. It serves as the binder for creating mobile apps using standard web development tools, for many different mobile platforms including iOS, Android and Windows Mobile. With PhoneGap, developers can

focus on the content creation, instead of worrying too much about the compatibility with different mobile platforms. PhoneGap has become an open source project called Apache Cardova. Meanwhile, PhoneGap is built into Adobe DreamWeaver and becomes a cloud-based service to compile HTML5-based apps.

With this set of technologies, the app development started as a web browser-based application with HTML5, CSS3 and JavaScript. Then the app was distributed to different mobile platforms with PhoneGap/Cordova as the binder. The benefit is lower maintenance effort because we only need to develop once for all mobile platforms, instead of once for each platform. The drawback is we cannot utilize many existing libraries written in Java or C/C++. This is also not suitable for apps with heavy duty graphical contents. However, for our "Engineering Economics Career" app, it is perfectly fine.

The HTML5 user interface is developed with Adobe DreamWeaver which provides an integrated environment for authoring and testing. However, one may choose to use a simple Notepad to write all the codes since the codes are in plain text. The developed web-based user interface is bound to different mobile platforms with PhoneGap. In the binding process, the development tool for each platform will be needed.

3. Development of the Mobile App "Engineering Economics Career"

Figure 1 shows the main interface. Figure 1(a) shows the story we made for the users, that is, this is to simulate the growth of an engineering economist in a virtual company. In Figure 1(b), we show that it the users can email their game progress to the instructors or anyone else. They can also share with other people through social media. What social media is available depends on the mobile user's actual device. For example, if a user has the Facebook app installed in the device, then one can share through Facebook. This allows viral dissemination of this app among the students through social media.

There are three accessory tools in the app: E-book, Calculator and Reference Tables. The E-book is a summary of the key concepts of Engineering Economics (Figure 2). Users may access this E-book from the main interface (Figure 1), or be directed to the relevant topics from a problem (see Figures 7~12).

The Calculator provides functions to solve basic engineering economics problems with formulas (Figure 3). There formulas are the most frequently used ones in the courses. Users may use them to help them solve more complex problems as part of whole solution procedures. Users may access them directly from the main interface (Figure 1), or from a problem (Figures 7~12).

The Reference Tables allow the users to compute discrete compound interest factors (Figure 4). Users may change the interest rate and years to see different tables as needed in solving their problems.
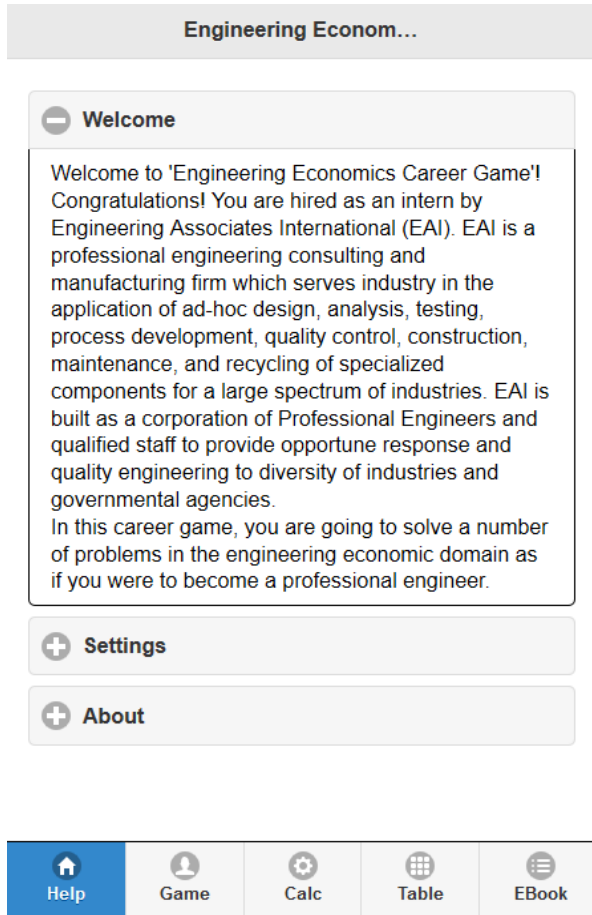
(a) The Main Interface
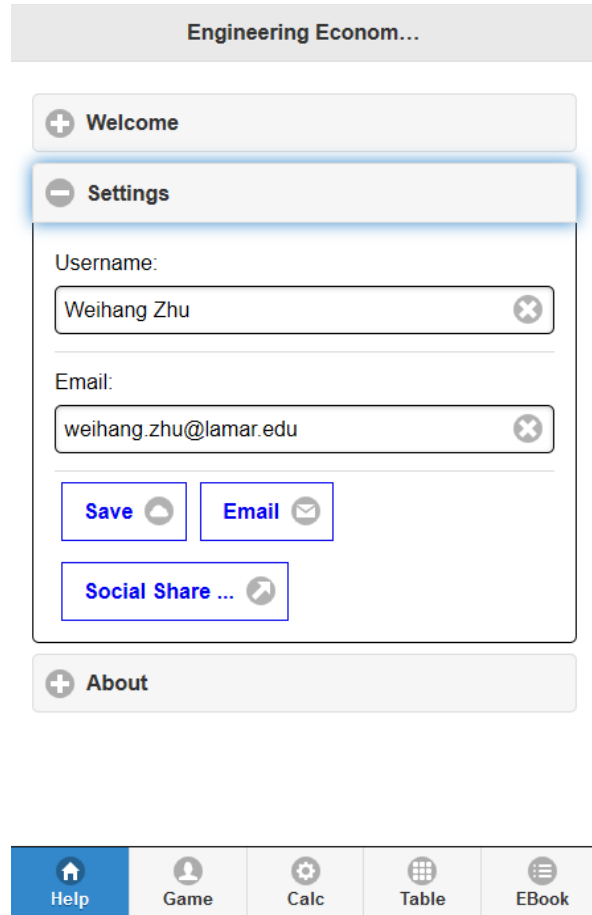
(b) The Main Interface with Interpretation

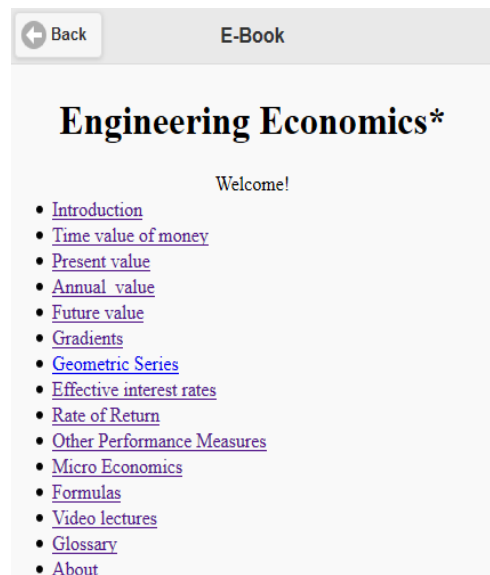**Figure 1**. The Main Interface of "Engineering Economics Career"

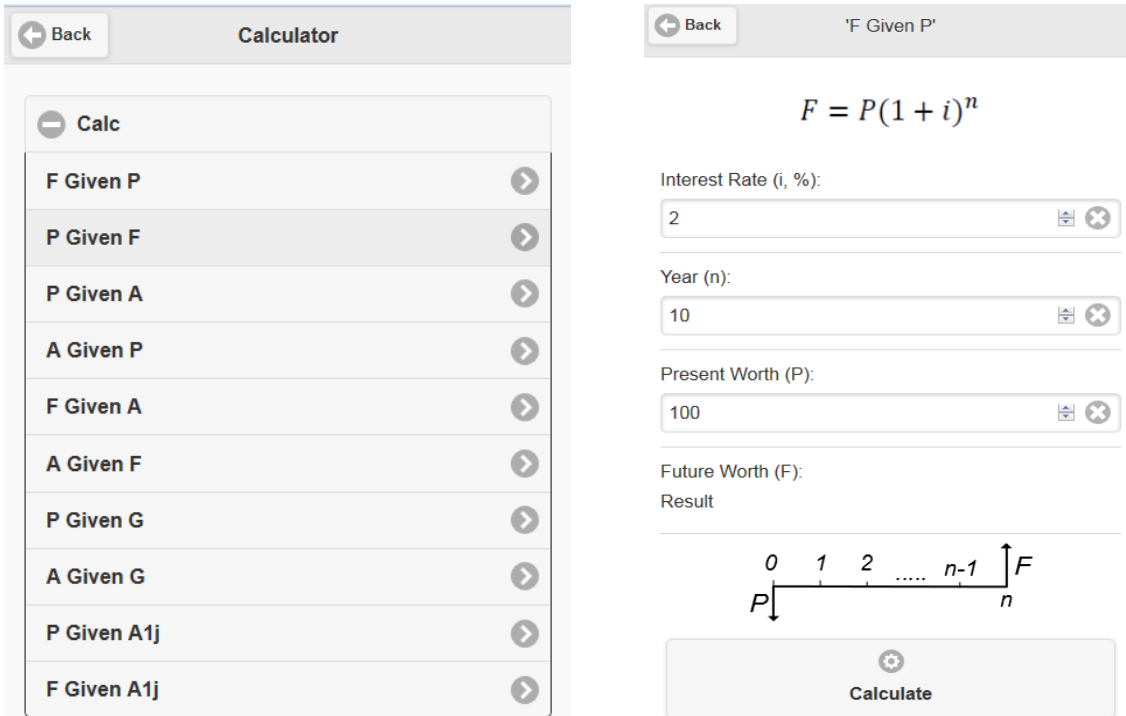**Figure 2**. Engineering Economics E-Book

Calculator

Back	**Calculator**

Calc

F Given P	⟩
P Given F	⟩
P Given A	⟩
A Given P	⟩
F Given A	⟩
A Given F	⟩
P Given G	⟩
A Given G	⟩
P Given A1j	⟩
F Given A1j	⟩

Back   'F Given P'

$$F = P(1 + i)^n$$

Interest Rate (i, %):

2

Year (n):

10

Present Worth (P):

100

Future Worth (F):
Result

Calculate

Figure 3. Engineering Economics Calculator

Compound Interest Factors

Interest Rate (i, %):

2

Update to Year (n):

10

View Reference Table

Interest Rate (i, %):

2

Growth Rate (j, %):

3

Update to Year (n):

10

View Table (A1,j -> P or F)

Rate: 2.0000%

F,P	P,A	F,A	PG,AG

Year	F|P	P|F
1	1.0200	0.9804
2	1.0404	0.9612
3	1.0612	0.9423
4	1.0824	0.9238
5	1.1041	0.9057
6	1.1262	0.8880
7	1.1487	0.8706
8	1.1717	0.8535
9	1.1951	0.8368
10	1.2190	0.8203

Back
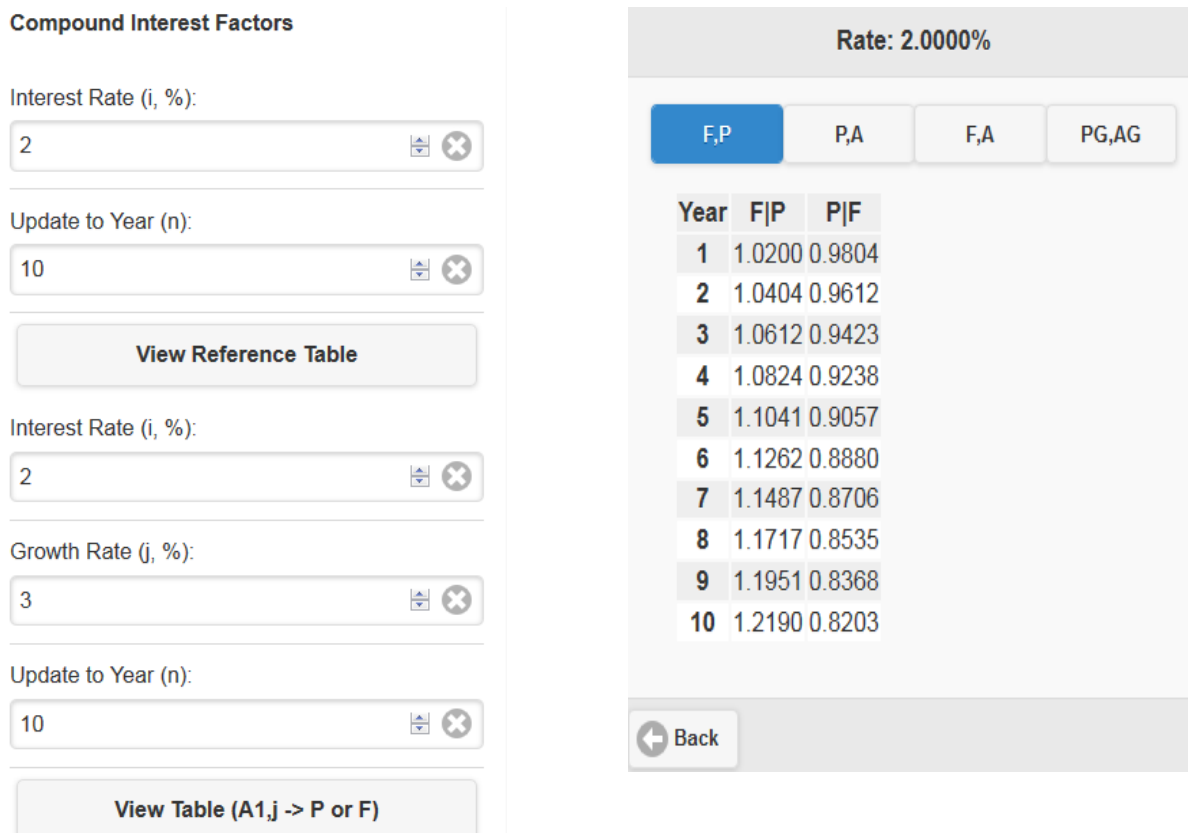
Figure 4. Engineering Economics Reference Tables

The main game interface has several components as shown in Figure 5. The 'Play' button will lead to the Career Game interface as shown in Figure 6. Five stages (levels) of the career are defined: Intern, Engineer, Senior Engineer, Head of Engineering and Chief Operations Officer (COO). Through this game, a user will be tested with a few conceptual problems and also work on a few calculation problems in order to make a few financial decisions. Five stages of the career are defined as Intern, Engineer, Senior Engineer, Head of Engineering and Chief Operation Officer. Each stage will have a selected number of conceptual and calculation problems. While a user can accept all stages, one must finish all problems in a stage in order to be promoted to a higher stage. Each problem carries some points. A user can work on a problem repeatedly in order to gain more points which are used to measure how much effort a user has spent on using the app and learning. The problem's options sequence or parameters are randomized. So each time users will see different questions. The 'Progress' button leads to the game progress report telling the user the current points, stage (level) and how many problems are completed in each stage (level).
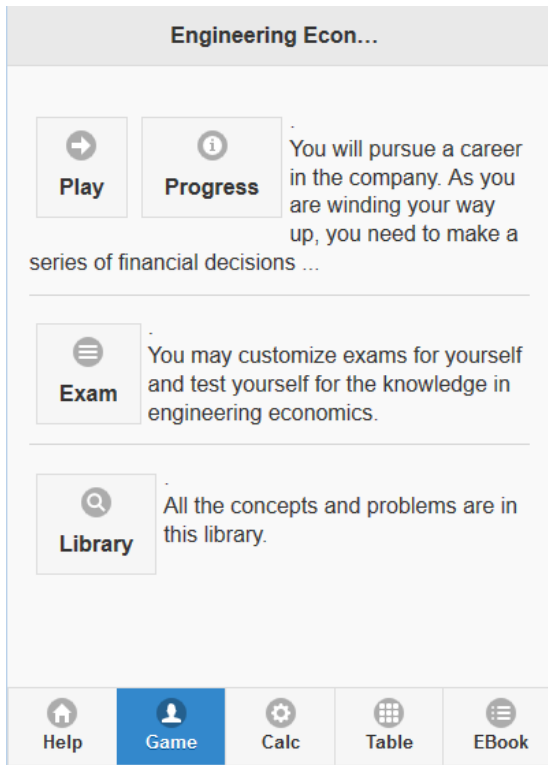

Figure 5. "Engineering Economics Career" Game Main Interface
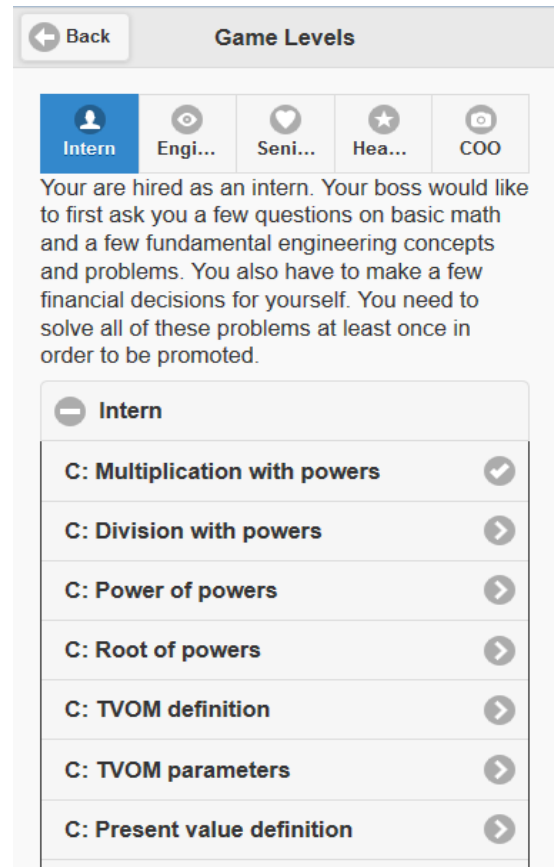

Figure 6. "Engineering Economics Career" Game Interface

Conceptual problems will check the users' understanding of fundamental concepts in Engineering Economics, starting from the basic algebra equations to more advanced concepts (Figure 7).

Figure 7. Conceptual Problem Interface

Figure 8. Example: Time Values of Money

Figure 9. Example: Sensitivity Analysis
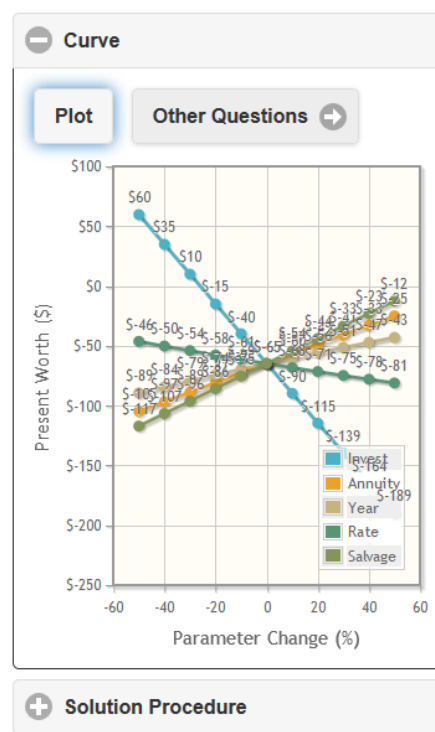
Different sets of calculation problems range from the simple questions on time value of money (Figure 8) to more complex concepts, such as Sensitivity Analysis (Figure 9), Project Alternatives (Figure 10), Monte Carlo Simulation (Figure 11) for risk assessment, and Supply Demand Equilibrium (Figure 12). These complex problems are accompanied with graphs which are generated with the help of jqPlot library. From the problem interface, users may access the

relevant topics in the E-book and use the calculator and interest tables to help themselves. After repeated training, users are expected to get more familiar with relevant topics and solution procedures.

Feasible alternatives

Question

Below you will find a table with the information about project alternatives. Please find the optimal decision based on maximum present value.

Project	A	B	C
Initial Investment ($)	575.00	314.00	449.00
Present value ($)	310.00	909.00	230.00

Constraints:
1) B is contingent on C
2) B and C are mutually exclusive.
3) Total available fund for investment is $1351.38

Your Answer:

0

Figure 10. Example: Project Alternatives

Monte Carlo Simulation

Calc ⚙   **Table** ⊞   **EBook** ☰

Question

The initial investment is between $382.00 and $642.00. The annuity is between $22.00 and $77.00. The life is between 11 and 6 years. The MARR interest rate is between 4.00% and 6.00%. The salvage value is between $52.00 and $150.00. Run a Monte Carlo Simulation with 300 random problems.

	Min	Max
Initial Investment	382	642
Annuity	22	77
life	11	6
MARR	4	6
Salvage value	52	150

What is the probability of present worth falling between $-164.40 and $267.00?

Your Answer:

Curve

Plot

Monte Carlo Simulation

The boundary values of bins: -452.00, -380.10, -308.20, -236.30, -164.40, -92.50, -20.60, 51.30, 123.20, 195.10, 267.00

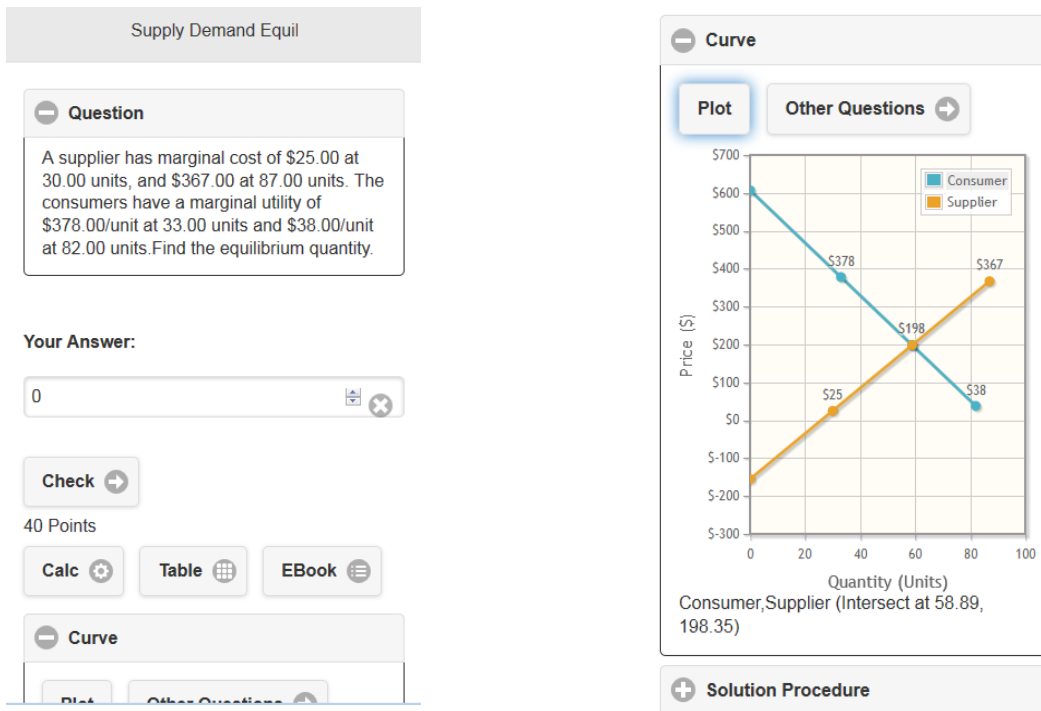**Figure 11**. Example: Monte Carlo Simulation for Risk Assessment

Figure 12. Example: Supply Demand Equilibrium

The 'Exam' button in Figure 5 leads to the interface in Figure 13. This interface allows a user to define exams and take exams to test the knowledge in Engineering Economics.
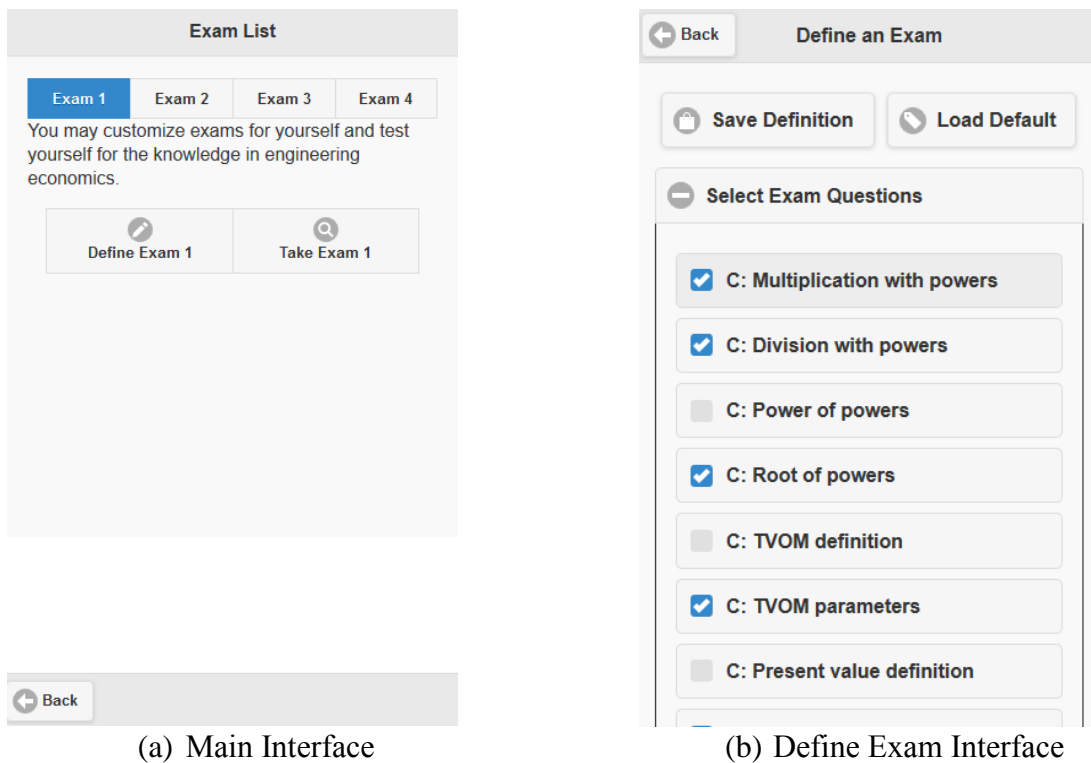

(a) Main Interface   (b) Define Exam Interface

Figure 13. Customize Exam to Test the Knowledge

Through E-book links, students have access to forty four videos produced for delivery of an online course (Figure 14). While most of the topics are covered, more videos are still in production to solve sample problems or cover more detail material as we see fit according to the students' feedback. Each video is about 10 minutes long, on specific topics, and is close captioned. The videos are uploaded to a private video streaming service that is paid by the University. With the data and video playing capabilities of smart phones, students have the possibility of not only practicing problems or reading a text book, but also being engaged as class attendants in an asynchronous lecture at their convenience. We constantly receive good review due to the fact the videos are short and to the point, reducing the distractions that students typically have when learning from long video lectures. In addition, Engineering Economics videos from Khan Academy are also added as supplementary materials.
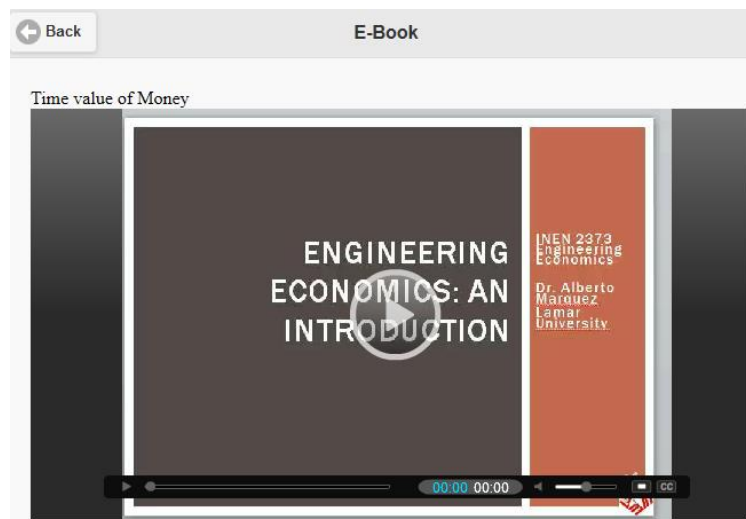

Figure 14. Example: Video Lectures Delivered through the E-book Links

4. Conclusion

Mobile apps for education have attracted more and more educators and researchers. However, in reality, most app developers are from software engineering background. They have decent programming experience but most of them do not have strong knowledge base in different subjects, such as those in the STEM disciplines. On the other hand, many educators have accumulated great knowledge in STEM subjects but they do not have enough technical background in developing an app. Synergy must be found between software developers and educators in the app development as well as the use of the app in the instruction process. This requires tight and frequent communication and formative improvement through the development and assessment loop. The HTML5 and JavaScript based app development lowers the technology bar for educators. Educators can develop most of the course contents with a popular webpage design software such as Adobe DreamWeaver and then pass the webpages to app developers to bind it into different mobile platform.

The "Engineering Economics Career" app has been made available freely through Apple App store and Google Play. We will continue to pursue formative assessment and improvement during the NSF grant period. In the future, we plan to continue to use this method to help other

educators to develop apps for their subjects. We foresee a proliferation of educational apps for students in the near future.

Reference

1. Sandberg, J., Barnard, Y.: Deep learning is difficult. Instructional Science 25, 15-36

2. Dahm, K., Newell, J.: Baseball Stadium Design: Teaching Engineering Economics and Technical communication in a Multi-Disciplinary. Journal of SMET Education, 9-12 (2001)

3. Dahm, K.: Teaching Engineering Economics Using a Web-Based Interactive Simulation. In : The 2003 American Society for Engineering Education annual Conference and Exposition (2003)

4. Mayer, R., ed.: The Cambridge Handbook of Multimedia Learning. Cambridge University Press, London (2005)

5. Zichermann, G., Cunningham, C.: Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps (1st ed.). Sebastopol, California: O'Reilly Media. p. xiv. ISBN 1449315399. (2011)

6. Ben-Zvi, D.: Toward understanding the role of technological tools in statistical learning. Mathematical Thinking and Learning 2, 127-155 (2000)

7. Zhu W., Marquez A., Yoo J.: Development of a Mobile App for Engineering Economics, ASEE Annual Conference 2013, Atlanta, Georgia, USA

8. Zhu W., Marquez A., Yoo J.: "Engineering Economics Jeopardy!" Mobile App Development and Student Satisfaction Assessment, ASEE Annual Conference 2014, Indianapolis, Indiana, USA

9. jQuery, JavaScript library for web development, http://www.jQuery.com/, accessed in January 2015

10. jQuery Mobile, JavaScript library for mobile app development, http://www.jQueryMobile.com/, accessed in January 2015

11. jqPlot, JavaScript plot library for web and mobile development, http://www.jqplot.com/, accessed in January 2015

12. PhoneGap, cross-platform mobile app development tool, http://www.phonegap.com/, accessed in January 2015