Title:
Development and Evaluation of a Mobile Platform for Teaching Mathematics of CAD subjects

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Introduction:

Starting from 2012, admission to bachelor's degree programmes at the university in Hong Kong is based on the Hong Kong Diploma of Secondary Education (HKDSE) examination results. Applicants are required to meet the general entrance requirements of the specific university including English Language, Chinese Language, Mathematics and Liberal Studies. There is no compulsory subject requirement in most universities. In other words, admission does not filter out students who do not have sufficient background on the underpinning subjects. As a result, a number of students were admitted to the engineering programmes without sufficient mathematical background. According to recent admission statistics of an engineering programme, less than half of the students studied the mathematics extended part module 1 (M1) or 2 (M2) in secondary school, which is considered to be important to those who study engineering programs at university.
Although freshmen are required to take several fundamental subjects in their first year, it is still a great challenge for them to learn or enhance difficult engineering mathematical knowledge in only one year. Engineering mathematics is fundamental to the learning of engineering subjects in years 2 to 4. The fundamental mathematical knowledge directly affects study of their future subjects, especially for the computer-aided product design (CAD) subjects. Referring to the syllabus of the CAD related subjects in various universities, finite-element analysis (FEA), deflection/ stress-strain analysis, two-dimensional (2D)/ three-dimensional (3D) transformation, projections, geometric modeling including curves and surfaces are the most important topics that is covered by the CAD subjects. Table 1 shows the research on the topics of the CAD related subjects in various universities. In spite of the CAD subjects in introductory level usually teaches students hands-on experience in using CAD tools and software, many CAD related subjects especially in advanced level requires students to understand the theory behind and do hands-on mathematical calculations. This not only requires student's imagination of the 3D model and geometries, sufficient engineering mathematics background such as linear algebra, polynomial, parametric equations, matrix algebra are also needed.
To the author experience, these engineering mathematics background of the students are usually associated with the performance of students in studying the CAD related subjects. Furthermore, it is reported that too much time devoted to review basic mathematical concepts at the beginning of many engineering subjects not only affecting the teaching progress, but also affecting the study progress of other students who have good mathematical background.

The development of mobile technology significantly influences the popularity and user experience of mobile learning. According to the 33rd statistical report on Internet Development in China released by China Internet Network Information Center (CNNIC) [4], the population of the mobile Internet users is 500 million and continuously growing. The role of mobile phones and other mobile platforms, and relative technologies affect both distance education and other aspects of the academic industries for

the future [1]. It can be foreseen that mobile learning will be important for future in both teaching and learning. Mobile learning is the ability to obtain or provide educational content on personal pocket devices such as smartphones and mobile phones. Educational content usually refers to digital information including notes and medias [7, 8]. Mobile learning can contribute a learner-centric conceptualization where knowledge can be enriching continuously and seamlessly [11]. Wong and Looi [12] have made attempts to consolidate almost all of the perennial design and pragmatic issues of mobile learning and characterized the mobile seamless learning (MSL) environment. Peng et al. [6] reported that the ubiquitous mobile technologies can help students to learn expediently, appropriately and learning immediately. Beth et al. [2] claimed that mobile devices are consumer-friendly because of its flexibility and high efficient. According to [9], around 95% of the 15-24 years old population own mobile phones. Using mobile phone for education is becoming popular, [10] created a mobile ready website for explaining English idioms. The website includes animation, video, textual materials and quiz. An evaluation has been conducted and proved that using mobile phone is educational effective.

Mobile learning enables learner to explore, identify and grasp the potential opportunities in daily lives, where learning and daily life can be integrated by the help of mobile technology. Despite a number of research has been conducted to investigate the effectiveness of using mobile platform for teaching, however most of the research is quite general and not much research has been conducted to investigate the effectiveness of teaching specific subject especially highly conceptual and mathematical relied CAD related subjects.

In this article, we propose to develop a student-oriented mobile application (App) teaching fundamental mathematics to enhance performance of students for learning CAD related subjects. The learning effectiveness of the developed application is justified by the test result between tests 1 and 2. Hypothesis test is used to determine whether the academic results have significant difference between both tests. Traditional teaching material such as notes and textbooks are used as the control experiment of this investigation. This article is organized as follow: section 2 introduces the developed learning platform, section 3 describes the research model used in this investigation, section 4 shows the data analysis results and section 5 concludes the findings.

	Topics			
Subject/ University	**FEA, deflection / stress-strain analysis**	**2D/ 3D Transformation**	**Projections**	**Geometric Modeling**
Computer aided product design/ The Hong Kong Polytechnic University	✓	✓	✓	✓
/ The Chinese University of Hong Kong		✓	✓	✓
Computer Aided Design/ The University of Texas at Dallas		✓	✓	✓
Computer Aided Design/ Columbia University	✓			
Computer-aided Design/ Luleå University of Technology	✓			✓
Computer-aided Design/ Johns Hopkins University	✓			✓

Tab. 1: Topics of the CAD related subjects in various universities.

Mobile learning platform:

The proposed engineering mathematics mobile learning platform is intended to provide a convenient and attractive channel for students to review and study the mathematics concepts and equations that need to be used in class. Although universities provide learning management system (LMS) such as

Blackboard to the students, however the materials in the LMS are usually provided to the students who have taken that mathematics subject. Other students are not able to access the necessary materials due to the authorization issue. It is difficult to authorize certain students to access specific mathematical materials. Students are also difficult to identify the necessary engineering mathematics concepts and equations that need to be used in class from a large amount of irrelevant reading materials in the LMS. Therefore, they are difficult to access and search the necessary materials efficiently. In order to encourage study and revision of the fundamental mathematical knowledge for the students, the platform should provide attractive and convenient channel to the students. The proposed M-learning platform contains materials that focused on particular engineering subjects. Students can search and identify the necessary reading materials easily. The M-learning platform also provides concise interface that enable students to search the necessary materials efficiently. In addition, the platform allows offline reading of teaching materials so that students can study anytime and anywhere. The platform is particularly useful to facilitate the education of students with different mathematical backgrounds. By strengthening their mathematical knowledge, it is expected that the learning outcomes of the CAD related subjects can be improved.

To develop a learning platform that fits users including teachers' and students' requirements, we have collected feedbacks from both students' and teachers' perspective. The details of the investigation can be found from the previous publication in [3]. In this investigation, we have designed two set of questionnaires for teachers and students respectively. The questions in the questionnaires are mainly focused on two aspects: (1) the required fundamental mathematic techniques and (2) the mathematics techniques that are difficult to the students. The required fundamental techniques refer to the mathematic techniques that need to be used in different subjects teach by the lecturers and the students think useful in their study. The mathematics techniques that students think difficult are self-assessed and judged by the students.

The investigation was conducted in the Department of Industrial and Systems Engineering (ISE) at the Hong Kong Polytechnic University. Seven lecturers teaching design related subjects was participated in this investigation. The design related subjects provided by ISE include computer aided product design, integrated design for manufacture, mechatronics for products, advanced engineering modeling, etc.

The results from the questionnaires are summarized as follows:

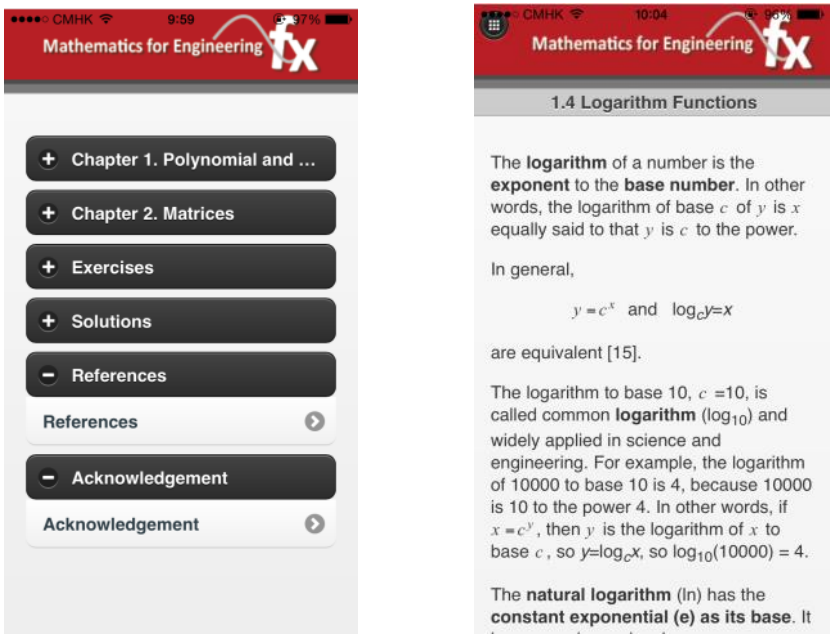
- Basic Mathematics (logarithmic functions, exponential functions, quadratic Functions, polynomial Equations, etc.) are required for all design related subjects
- Statistics, matrix algebra and coordinate geometry are also important to most of the subjects
- Most of the lecturers agreed that students have difficulty in most mathematics techniques

Then, another set of student feedback questionnaire was distributed to the students during lessons. 148 valid questionnaires were received and the results are summarized as follows:

- More than of half of the students pointed out that the most difficult mathematic technique is matrix algebra (including calculation of determinant, matrix inverse, solving system equations, Gaussian elimination, etc.)
- Students also find difficulty in studying basic mathematics and statistics
- Most of the students prefer to use mobile Apps instead of other university's internal learning platform such as Backboard
- The most common mobile operating system used by the students are Android and Apple IOS corresponding to over 58% and 25% of the students respectively
- Most of the students (41%) suggest that exercises and notes are the most useful components in the mobile learning platform for their study
- Most of the students prefer a simple, user-friendly and well-organized structure App interface for the design of the mobile learning platform

Based on the results from feedback questionnaires, most of the students have difficulty in fundamental engineering mathematical knowledge and therefore affecting the performance in studying engineering design subjects. Most of the teachers believe that improving engineering

mathematics technique can also improve the performance of students studying design related subjects. In this project, we propose to develop a mobile ready website and an App that can be used both Apple IOS and Android platforms for the students in order to provided different channels for the students studying with mobile platforms.
On the other, we have adopted opinions from the students and the suggestions by Pelton, T. and Francis Pelton [5] that the design of education App should be simple and minimizing distractions like background music and flashing effects. To provide a more comprehensive reading experience for the users, the App also provides useful manipulative such as examples and descriptions. In summary, the App design is user-friendly, less stress and success-oriented in order to build up students' confidence and increase their study motivation. Figures 1 show the snapshots of the designed mobile App. Figure 1 (a) shows the content page of the App with collapsible index. Figure 1 (b) shows the content of an engineering mathematics topic. The content provides both descriptions and examples to the students. Apart from these, the App also provides exercises and solutions for the corresponding topics such that students can practice immediately after studying each topic.



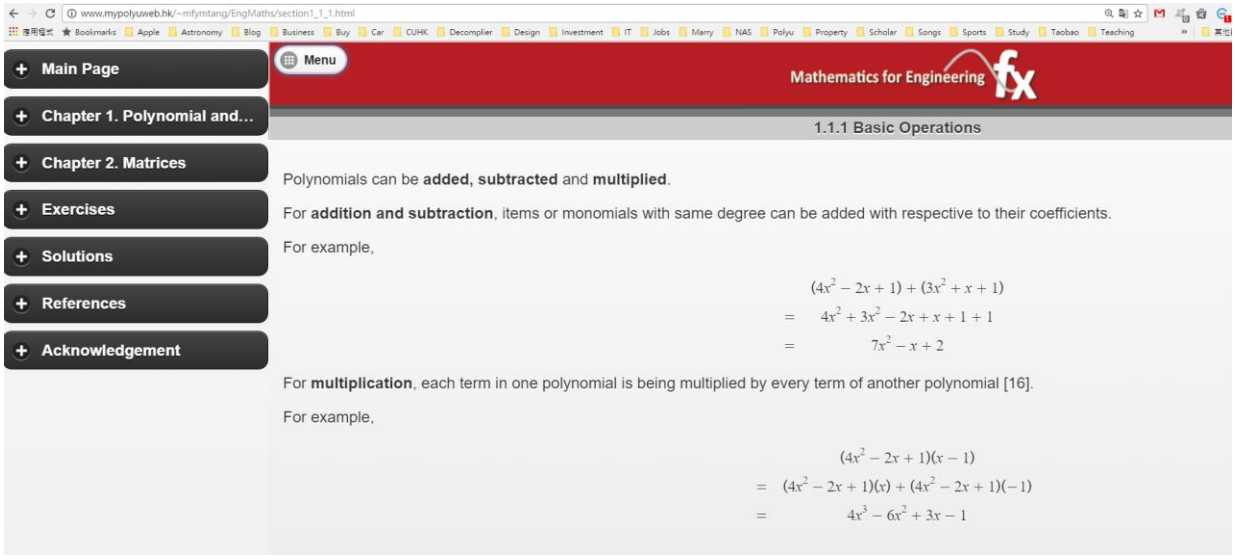
(a) (b)

Fig. 1: Snapshots of the developed mobile application. (a) Content page with collapsible index. (b) Descriptions and examples of an engineering mathematics topic.

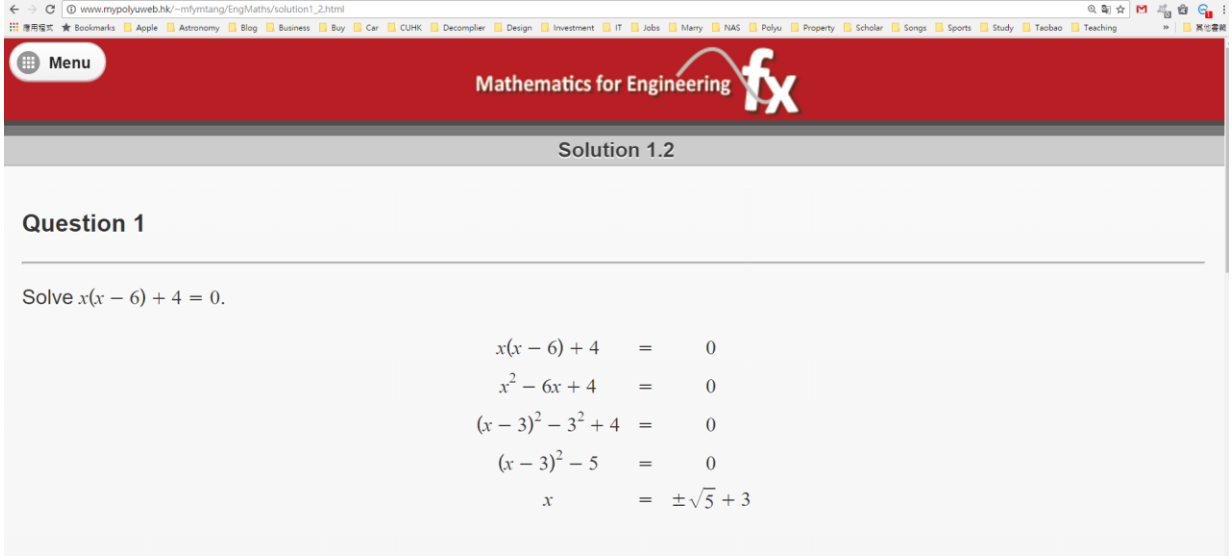
Figures 2 shows the mobile ready website. The content is the same as the App version. The first page of the App and the website is the content page. It includes two major mathematics topics: (1) Polynomial and Exponential Functions and (2) Matrix Algebra. The mathematics topics are based on the survey result. It also provides exercises and solution for each corresponding topic for their revision. A list of references is also provided so that students can explore further information from the internet if necessary.

Research model:
The purpose of this project is to encourage self-learning of the students and provide a convenient channel for students to review and study fundamental mathematical concepts and equations that are

needed in the CAD related subjects. Therefore, an evaluation was conducted to evaluate the performance of the students.



(a)



(b)

Fig. 2: Snapshots of the mobile ready website. (a) Collapsible content page and the teaching content. (b) Examples and solutions for each mathematics topic.

At the commencement of the teaching semester, both learning supports – mobile application (App) and traditional notes were introduced to the target students. They are required to choose one of the learning support by themselves for the coming two tests. About two weeks was given to the target students to review and study the required mathematical knowledge using the developed platform or notes. The first test was conducted to measure the mathematical capability of the students. They need to declare what is their major learning support and use the same learning support for the second test.

About one and half month later, the second test was conducted to test the students' capability on the required mathematical knowledge again. The questions between two set of tests are totally different but at the same level of difficulty. The results from the tests 1 and 2 were compared to evaluate the students' performance for the tests. 100% is the full mark for the tests and average marks of the students were calculated. Immediately after each test, the students were also required to complete a feedback questionnaire. The feedback questionnaire consisted of two sections in order to collect qualitative information. The first section includes the learning supports used by the students and their mathematical background. The second section includes students' comments and opinions on the platform and teaching materials.

Following are some of the questions used in the tests:

- Matrix algebra
- Gaussian elimination
- Matrix inverse
- sub-matrices problems

In our investigation, students study the subject "Computer-aided Product Design" was participated in the tests. A commercially available statistical analysis package SPSS V17.0 was used for analysis of the data. The paired *t*-test with 95% confidential level was used to compare the results between pre-and post-tests. A *p*-value of <0.05 was considered as statistically significant.

Data analysis and results:

In our study, 80 students were participated on both test 1 and test 2. The students were divided into two groups with and without mathematical background. For those students who have studied matrix algebra before were classified as the group with mathematical background. The rest of the students were classified as the group without mathematical background. Tables 2 and 3 show the average marks for the test 1 and test 2 between the students using notes and App, with and without mathematical background respectively. It was found that the average mark between test 1 and test 2 was significant increased (p = 0.001) no matter students using notes and App during their study. However for those students without mathematical background, they only made significant improvement when using mobile application (p = 0.004). The average mark did not show a significant improvement when using notes in their study (p = 0.934 > 0.005). The results show that for those students with mathematical background, the designed teaching materials and App can help them to gain a better result in Matrix Algebra. For those students without mathematical background, the mobile learning platform can help students in improving their performance rather than traditional teaching notes. One may suggest that these students may not have sufficient motivation in studying mathematics. A convenient channel can facilitate the students without mathematical background studying anytime and anywhere. More supports should also be provided to increase their interest and self-autonomous in their study. However, further investigation on their problems and difficulty is needed to design a suitable teaching supports to them in the future.

	Mean scores				
	Test 1	Test 2	Mean Different	*N*	*P*-value
Using Notes with mathematical background	56.42	77.92	21.250	24	**0.001**
Using App with mathematical background	54.62	75.80	21.180	25	**0.001**

Tab. 2: Average marks of tests between the student using notes and App, and with mathematical background.

Mean scores

	Test 1	Test 2	Mean Different	*N*	*P*-value
Using Notes without mathematical background	51.00	52.50	19.500	12	0.934
Using App without mathematical background	35.00	54.47	19.474	19	**0.004**

Tab. 3: Average marks of tests between the student using notes and app, and without mathematical background.

Conclusion:

This study designed a student-oriented mobile application which aims to enhance performance of students learning CAD related subjects by engineering mathematics. The performance of the students is justified by the average tests results between test 1 and test 2 by using App and traditional notes. The study divided the students into two groups with and without mathematical background. It was found that for those students with mathematical background, they made significant improvement when using both App and traditional notes. However, for those students without mathematical background, they only made significant improvement when using App. Despite this study intended to investigate the effectiveness of the developed application through academic test results, there are several limitations for this study. First of all, to the author experience, the engineering mathematics background of the students are usually associated with the performance of students studying CAD related subjects. However, more experiments should be conducted to investigate the association between students' mathematical background and their performance in studying CAD subjects. Secondly, due to the limitation of the class size, the sample size of the investigation still small especially that the investigation has divided the students into two groups with and without mathematical background. It is because the data is obtained from one academic year only. In the future, we have to increase the number of sample size by including the results of the students in other academic years. Thirdly, although the students have declared the major learning supports used in their study, it is still difficult to filter out those students using both learning supports in their study. It is also assumed that the students answered the questions honestly. In order to ensure the students are fully devoted into the tests, the tests are used as one of the assessment component of the subject which share 10% of the total marks. However for the fairness reason, we cannot control the use of the learning support of the students. Students' study time may also various among of them and affect the results. More investigation can be done based on students' study time in the future.

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References:

[1] Altbach, P.G.; Reisberg, L.; Rumbley, L.E.: Trends in global higher education: Tracking an academic revolution, 2009, A Report Prepared for the UNESCO 2009 World Conference on Higher Education.

[2] Beth, B.; Kathryn, L.: Mathematical Apps and Mobile Learning. Society for Information Teaching and Teacher Education International Conference, 38409, 2012.

[3] Cheung, T.L.; Tang, Y.M.; Law, K.; Yung K.L.; Chen, H.Y.: Design an M-learning Platform for Engineering Mathematics, Proceedings of the 11th International Conference on Technology Education (ICTE) in the Asia Pacific Region, Hong Kong, 3-5 January 2015, pp. 141-144

[4] China Internet Network Information Center: Statistical Report on Internet Development in China, 2014

[5] Pelton, T.; Pelton, F.-L.: Design principles for making meaningful mathematics apps. In M. Koehler & P. Mishra (Eds.), Proceedings of Society for Information Technology & Teacher Education International Conference, 2011, 2199-2204.
[6] Peng, H.; Su, Y.; Chou, C.; Tsai, C.: Ubiquitous knowledge construction: Mobile learning re-defined and a conceptual framework. Innovations in Education & Teaching International, 46(2), 2009, 171-183. https://doi.org/10.1080/14703290902843828
[7] Pinkwart, N.; Hoppe, H.-U.; Milrad, M.; Perez, J.: Educational scenarios for cooperative use of Personal Digital Assistants Journal of Computer Assisted Learning 19(3), 2003, 383-391.
[8] Quinn, C.: mLearning. Mobile, Wireless, In-Your-Pocket Learning. Linezine. Fall, 2000. Available at http://www.linezine.com/2.1/features/cqmmwiyp.htm.
[9] Taylor Nelson Sofres Interactive eNewsflash: Survey charts emerging mobile phone, internet, and WAP trends in Asia pacific. Retrieved on December 19, 2002 from www.tnsofres.com/emailer/news_item.cfm?news_ID=88
[10] Thornton, P.; Houser, C.: Using mobile phones in education, Wireless and Mobile Technologies in Education, IEEE International Workshop on, 2004, 3.
[11] Wong, L.: A learner-centric view of mobile seamless learning. British Journal of Educational Technology, 43(1), 2012, E19-E23. https://doi.org/10.1111/j.1467-8535.2011.01245.x
[12] Wong, L.-H.; Looi, C.-K.: What seams do we remove in mobile assisted seamless learning? A critical review of the literature. Computer & Education, 57(4), 2011, 2364-2381.