Mobile Multimedia Instruction for Engineering Education: Why and How

Ataollah Zarei, Khairiyah Mohd-Yusof, Mohd Fadzil Daud
Center for Engineering Education, Universiti Teknologi Malaysia
Dayang Tiawa Awang Hamid
Sports Innovation Technology Centre, Universiti Teknologi Malaysia

Abstract

Multimedia and mobile learning instructions are two important educational technologies which can be combined to have more effective teaching and learning experience. Regarding the lack of study in this area, the aim of this study is to answer the question as to why mobile multimedia instruction should be used and how it should be designed, especially for engineering education. The reasons for using mobile multimedia learning and instruction for engineering education are: migrating users from desktop to mobile, ubiquitous support, compatibility with net generation learning styles, increasing students' motivation, supporting situated learning and increasing engineering students' professional skills. In addition, design-based research method is suggested for developing mobile multimedia learning instructional design for engineering education is proposed and a first version of mobile multimedia instructional design principles by combining and synthesizing existing design principles of mobile and multimedia learning is suggested.

Keywords: Multimedia learning, mobile learning; mobile multimedia instructional design principles; engineering education; educational technology

Introduction

Engineering education is changing because it is under a huge pressure from society and industries to increase its effectiveness to prepare a new generation of engineers who can face global issues such as population, transportation, global climate change, sustainable energy, global poverty, and affordable quality health care (Grasso & Burkins, 2010; National Science Board, 2007).

According to (ABET, 2015), the engineering students not only be able to apply the scientific knowledge in practice and design proper experiments, systems, components and processes, but they should also have enough professional skills such as engaging in life-long learning, identifying, formulating and solving engineering problems, effective communication and so on. These objectives are not accessible in traditional approach to engineering education (Felder, 2012).

In other hand, declining interest in studying engineering among high school students, low professional skills such as communication skills, critical, analytical and creative thinking among engineering graduates (Felder, 2012), cause the shortage of competent engineers in many countries such as U.S (National Science Board, 2007), U.K (Spinks, Silburn, & Birchall, 2006), Germany (Blau, 2011) and Malaysia (Jayarajah, Saat, & Rauf, 2013).

According to Felder (2012), improving teaching and learning theories, educational technologies, shifting program accreditation focus from documentation to outcome-based, decreasing traditional engineering jobs are other factors that drive engineering education to a paradigm shift from behaviorism to constructivism (Felder, 2012; Jamieson & Lohmann, 2012). This reform covers engineering curricula, teaching and learning methods and ways that engineering students and instructors use educational technologies (Felder, 2012). Therefore, there is a need to study educational technologies especially emergent ones and investigate effective ways of applying these technologies for improving engineering education to prepare new generation of engineers.

Mobile multimedia learning and instruction is an innovative way to increase the effectiveness of multimedia learning and instruction for engineering education by empowering it through mobile devices capabilities. Although desktop-based multimedia instruction showed its effectiveness in improving students' learning of engineering subjects (Junaidu, 2008; Sidhu, 2007), media access method and tool are changing from desktop to mobile. Engineering students, like others, usually use their mobile phones to access Internet, watch multimedia materials and so on even in time slices before or after their classes. According to ComScore reports, in the U.S., the time spent on mobile apps exceeded desktop web access in Jan 2014 (comScore, 2014) and in Germany mobile video users grew by 215% whilst online video via desktop PC or laptop users grew only 1.5% (comScore, 2013). Also, according to YouTube statistics, 50% of its global watch time comes from mobile devices like smart phones and tablets (YouTube Statistics, 2015).

In addition, continuous improvement in mobile phone technologies and features such as audio/video recording and playing features, 3G/4G internet access, GPS, accelerometer, gyroscope, Compass, provides lot of opportunities to improve teaching and learning quality. However, the most important questions before using educational technologies especially new ones are why and how questions. In the other words, these two questions should be answered before using it:

- Why should the engineering instructors and instructional designers use mobile multimedia learning?
- How should it be designed?

Regarding the lack of papers answering these questions, this paper tries to answer them.

Mobile Multimedia Learning Benefits for Engineering Education

To elaborate how mobile multimedia learning can improve teaching and learning engineering subjects, we will discuss about the existing challenges of teaching and learning engineering subjects which can be solved by multimedia instruction. Then, multimedia instruction solutions that solve or reduce these problems will be explained and finally mobile multimedia learning enhanced solution will be elaborated. As it is shown in Table 1, mobile multimedia learning not only can improve engineering students' fundamental skills, but also has a big potential to improve engineering students' professional skills. These two issues are elaborated in following subsections separately.

Table 1: Summary of mobile multimedia learning advantages for engineering education

Problems facing T&L engineering skills	Multimedia Instruction Solutions	Mobile Multimedia enhancements
The challenges of T&L engineering subjects (fundamental skills) • Understanding difficult concepts and procedures (Ozcelik & Acarturk, 2011; Sidhu, 2007) • Neglecting from students' differences in learning styles and speed in traditional teaching methods(Felder, 2012; Patterson, 2011) • Insufficient, low quality or lack of learning resources such as course books, class time, instructors and lab facilities (Cadoni, Botturi, & Forni, 2008; Lau, Mak, & Ma, 2006; Yueh, Lin, Huang, & Sheen, 2012) • Poor Motivation among students (Felder, 2012; Fraile-Ardanuy, Garcia-Gutierrez, Perez, & Fraile-Mora, 2009)	• Proper combination of text, narration and visual elements (Patterson, 2011; Sidhu, 2007; Sorden, 2012) • Adding Multimedia learning materials to support textbooks (including CD or referring online resources) (Lau et al., 2006; Sidhu, 2007)	Enhanced combination of learning elements • combining real life situations and artifacts with virtual data and illustration via mobile augmented technology (Mejías Borrero & Andújar Márquez, 2012) • Reducing students' cognitive load comparing to desktop-based mm in some situation (Ozcelik & Acarturk, 2011)
	Interactivity • Enable students to control learning flow (Lau & Mak, 2004b; Sorden, 2012).	Enhanced interactivity • Interaction with the material (Feng et al., 2014) • Interaction with the environment (Ryokai, Agogino, & Oehlberg, 2012)
	Accessible (off-class) • Computer-based (Sidhu, 2007) • Web-based (Junaidu, 2008)	Enhanced access • Ubiquitous Access to the learning materials (Support Gen Y) (Elias, 2011b; Redecker, 2008). • Supporting contextual multimedia learning and instruction (Ryokai et al., 2012). • Effective use of existing multimedia materials by contextualizing them (Ryokai et al., 2012).
T&L professional skills challenges (Felder, 2012)	Engaging students in real life problems via multimedia case study approach (Lau & Mak, 2004a; Sankar, Kawulich, Clayton, & Raju, 2010).	facilitating multimedia material creation in the context, and reflection and discussion on the materials by the students (Elias, 2011b).

Problems and Challenges Facing T&L Engineering Subjects

There are several challenges facing teaching and learning engineering subjects such as understanding difficult concepts and procedures, neglecting from students' differences in learning styles and speed in traditional teaching methods, Insufficient, low quality or lack of learning resources such as course books, class time, instructors and lab facilities and Poor Motivation among students.

Some engineering subjects are difficult to teach and understand and teachers and students should be assisted to overcome this issue via different ways and tools (Ozcelik & Acarturk, 2011; Sidhu, 2007). It is impossible to achieve some crucial learning objectives such as applying the scientific knowledge in practice and designing proper experiments, systems, components and processes (ABET, 2015) without understanding basic concepts.

Also, neglecting from students' differences in learning styles and speed in traditional teaching methods is a big drawback of traditional teaching methods. Engineering students are mostly visual and sensing learners. It is clear that direct lecturing, which is mostly verbal, cannot meet engineering students learning style and this incompatibility decreases students' learning achievement (Felder, 2012; Patterson, 2011). Another problem of traditional teaching method is the teaching pace is too fast for a part of students and too slow for another part, so they cannot follow the instructor and do not learn well. The students' learning speed is different mainly because of their previous knowledge but the teaching speed is same for all (Sidhu, 2007).

In addition, insufficient or low quality of learning resources such as course books, class time, instructors and lab facilities have been mentioned as major problems in teaching and learning engineering subjects by the researchers. For example, Lack of instructors is one of the challenges that mentioned by the researchers. According to Felder (2012), engineering courses should be taught by the experts in diverse forms of scholarship including discovery, integration, application and teaching and learning. Also, Lack of laboratory facilities is also a big challenge for engineering universities. For example, lack of laboratory facilities for executing experimental tests for and with civil engineering students was reported by (Cadoni et al., 2008). They also emphasized executing some experimental tests are very expensive. For example, the cost of executing a bending test on a 9 meters long reinforced concrete beam about 15,000 US$. In some cases it is impossible to provide real experience in the labs. For example, it is impossible to make real experience for deep excavation for geotechnical engineering students in the labs (Lau et al., 2006). Furthermore, time limitation is another problem faces traditional teaching methods. For instance, insufficient class time for teaching technical drawing (Penin, Morales, Garcia, Diaz, & Quiros, 2004) and laboratory activities (Cadoni et al., 2008) are mentioned by the researchers. Also, students' absent from the class due to the rigid schedule is another challenge which is reported by the researchers. In fact, there many reasons hinder engineering students to attend in the classroom and teachers should have a plan to support their students based on their time and place (Laoui & O'Donoghue, 2008; Munoz-Abella, Alvarez-Caldas, & Rubio, 2011). In addition, incomprehensibility of engineering course books as one of the students learning barriers was reported by the researchers. Although engineering course books usually include some pictures, however, explaining some concepts and processes such as Domain Name System in computer networks course or motion path algorithm for curvilinear motion in mechanics dynamics course is very difficult by the static or even 2D dimension animations (Ozcelik & Acarturk, 2011; Sidhu, 2007).

Motivation challenge is another teaching and learning problem facing engineering students and instructors. Students' motivation is crucial for learning engineering courses (Fraile-Ardanuy et al., 2009). However, traditional teaching methods which cannot support engineering students' learning styles is a key factor reducing students' motivation (Felder, 2012). Furthermore, Students' interest for learning a subject is not same and their view of the subject's relevance to their need is different. For example, (Fraile-Ardanuy et al., 2009), stated that learning electrical machinery course is not attractive for civil engineering students (Fraile-Ardanuy et al., 2009).

Multimedia Instruction Solutions

Generally, multimedia instruction can overcome or reduce the mentioned challenges via mixing three basic strategies: proper combination of learning elements, interactivity and accessibility. Proper combination of text, narration and visual elements reduces students' cognitive load and increase their cognitive engagement. Therefore, it helps them to learn easier and faster (Patterson, 2011; Sidhu, 2007; Sorden, 2012). Also, interactive multimedia learning materials enable students to stop, start, forward and backward the learning materials so they can learn in their own speed and more interactive approaches such as multimedia simulations increase students' engagement (Lau & Mak, 2004b; Sorden, 2012). Furthermore, the students can access to the learning materials in off-class situations via their desktop computer connected to the Internet and learn based on their needs and time (Cadoni et al., 2008; Junaidu, 2008). These strategies can solve or reduce the mentioned T&L challenges and improves their quality via different ways.

Using multimedia instruction in T&L engineering subjects reduces the gap between traditional teaching styles and students' learning styles. For example, Sidhu (2007) asserted that it is impossible to show curvilinear motion of a robotic arm while moving from one point to another, necessary for explaining motion path algorithm via traditional teaching methods or even static graphics or 2D animation, and so, used 3D animation to explain this algorithm.

Furthermore, some educational resources can be replaced by the multimedia materials. For instance, expensive structural tests in civil engineering labs can replaced by multimedia simulations (Cadoni et al., 2008). Also, using multimedia instruction method in the classes can help engineering instructors to explain difficult concepts and procedures easily and fast, so it can reduce teaching time (Álvarez Peñín, Pérez Morales, García, Díaz, & Ouirós, 2004; Junaidu, 2008; Sidhu, 2007).

Increasing engineering students' motivation via different ways is another benefit of multimedia instruction. It can attract students' attention by visualization (Benkrid & Clayton, 2012; Keller, 2008), make relationships between knowledge and practice via illustrating real situations (Keller, 2008; Yuen & Naidu, 2007) and increasing students' self-confidence and satisfaction via increasing their academic achievements (Keller, 2008; Mulop, Mohd Yusof, & Tasir, 2014).

Mobile Multimedia Enhancements

Mobile multimedia instruction can improve the quality of desktop-based multimedia instruction by enhancing the quality of its basic strategies including accessibility, interactivity and proper combination of multimedia elements.

Enhanced accessibility: According to Gottfredson and Mosher (2012), there are five basic moments of learning needs: learning for the first time, wanting to learn more, trying to apply previously learnt knowledge, when things go wrong and, finally, when things change. The unique technology which can support students in these moments is mobile technology and multimedia is an effective way of knowledge delivery (Elias, 2011b).

It is clear that mobile-based multimedia materials are more accessible than desktop-based multimedia materials. In addition, mobile multimedia instruction is more compatible with new generation of engineering student learning styles than desktop-based multimedia instruction. Because, compared to the previous generation, the current generation of the engineering students are more pragmatic and impatient which means they need immediate support in the context (Redecker, Ala-Mutka, Bacigalupo, Ferrari, & Punie, 2009). Furthermore, supporting engineering students by providing ubiquitous access to the learning materials improves their motivation for learning (Keller, 2008).

Enhanced Interactivity: Mobile multimedia learning provided new ways of interaction due to the Smartphones facilities and sensors such as camera, GPS, accelerometer, NFC and gyroscope, provide new methods of interaction. For example, wearable technologies and tools such as Google Glass provide new ways of interaction between learners, contents and location which can improve the quality and effectiveness of multimedia learning. Although, these technologies have not been broadly used for engineering education yet, however, there is a huge potential in applying these technologies to improve teaching and learning engineering courses. Successful experiences in using these technologies for improving teaching and learning other fields such as health and medical sciences support our claim (Feng et al., 2014).

Also, *Location-Aware* technologies provide a way of interaction with the real environments. *Location-Aware* mobile apps can suggest proper multimedia learning materials for engineering students based on their location. These apps contextualize existing multimedia learning material databases to enhance students' learning. For example, Ryokai et al. (2012) developed a smartphone based application for learning biodiversity, named GreenHat mobile, to increase students' motivation and learning. This application explores the engineering pathway digital library and alerts students about nearby learning opportunities based on their location. Students then were watching multiple expert videos with different viewpoints, at the location, discussing issues surrounding the argument. Research studies show that mobile augmented reality can increase students' learning (Ryokai & Agogino, 2013).

Enhanced combination of multimedia learning elements: Smartphones provide facilities to combine virtual multimedia learning elements with real physical world via mobile augmented technology. This technology makes a virtual layer of information over the real world (Cheng & Tsai, 2013) and combine real situations with virtual elements like text, graphics and so on. This technology opens new windows for multimedia learning and innovative applications. For example, Mejías Borrero and Andújar Márquez (2012) developed a an augmented reality lab system for two subjects of electrical engineering including Digital Systems and Robotics, and Industrial Automation in which virtual elements interact with real ones. This system enables students and teachers to remote-work in their classroom. Mobile augmented technology can also add visual elements such as 3D illustrations and animations to the engineering course books. This method can enhance students' learning even better than desktop-based multimedia instruction in the same condition. For instance, a research study showed that by adding QR codes to computer networks course book and using smart phones to watch related multimedia animation while reading the book, students' retention improved more than the other groups who use the book and watching multimedia animation on a laptop or PC. This is due to the reducing spatial distance between text and animation if animations are shown on the smartphone putting on the book. Furthermore, students were more interested in using this method (Ozcelik & Acarturk, 2011).

All the mentioned enhancements make the multimedia learning more contextual and situated. According to J. S. Brown, Collins, and Duguid (1989), "learning methods that are embedded in authentic situations are not merely useful; they are essential". From the situated learning approach, knowledge should be presented in an authentic context (Lave & Wenger, 1991). Therefore, using teaching methods such as mobile multimedia learning and instruction which support situated learning is essential for engineering education.

Mobile Multimedia Solutions for Improving Professional Skills

Professional skills such as engaging in life-long learning, identifying, formulating and solving engineering problems, effective communication and so on are as important as technical skills (ABET, 2015). Lack of these skills among engineering graduates has been reported by the researchers Traditional approaches and teaching methods do not provide enough opportunity for improving these skills (Felder, 2012). Improving students' professional skills, as one of the missions of the emerging paradigm to engineering education, usually cannot be done through a specific course. Instead, improving theses skills should be considered along engineering curriculum (Felder, 2012).

Mobile multimedia facilitates different processes which are essential to improve engineering students' professional skills including multimedia material creation, sharing the materials, reflection and discussion on them. Smart phones facilities and apps to record videos, take photos, editing, labeling, relating or linking any types of contents to a specific object or position and publishing them through social media or professional networks provide unique opportunity to improve engineering students' professional skills.

The process of multimedia material creation in authentic situations can be facilitated via Smartphones or Tablets. For example, engineering students of landscape architecture and environmental science can capture their environment through taking photos, recording audio and video and annotate visual elements by using the GreenHat mobile application. This app not only records the time and location of the captured material automatically, but also enables students to add tags to the material. These learning activities develop student approaches to location-sensitive controversial conservation issues (Ryokai et al., 2012). Also, these mobile devices connected to 3G/4G internet can support engineering students to reflect and discuss on the multimedia learning materials whenever they want (Moore, Kerr, & Hadgraft, 2011; Ryokai et al., 2012). Such activities enhance students' learning (Lave & Wenger, 1991; Mayer, 2005).

Mobile multimedia learning and instruction can help students to improve their professional skills. Consider engineering students see some problems in their environment which usually other people don't care and capture and publish them. For example, a civil engineering senior student sees a problem in a bridge or building during the construction process. He can captures the problem and add some explanation, labels it and relates it with the specific location and publishes it via different ways and tools. The process of posing problem increases students' critical thinking (Priest, 2009) which is basic for engineering students (Felder, 2012) and also can help the practitioners to be aware and solve the problem.

Furthermore, the ability for seeing problems, especially in the context, is a creative skill which is essential for engineers (ABET, 2015). Einstein & Infeld (1966, as cited in Lavy & Bershadsky, 2003) wrote: "*The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skills. To raise new questions, new possibilities, to regard old questions from a new angle, requires creative imagination and marks real advance in science*". The new innovative question or idea and its context, as a multimedia content, should be recorded at the same place and time, else may be forgotten by the students. Therefore, supporting systems such as mobile apps and networks to record and publish the idea or problem for further process play a unique role to support students' creativity.

It is noteworthy that making multimedia material should not be considered as a simple combination of text, narration and visual elements. In fact, students should achieve the ability to explain and visualize engineering problems, ideas and solution for their expert or non-expert audience to attract and convince them via digital media. This ability can be categorized as digital communication skill (Gardner & Willey, 2011) which is as important as face to face communication skills for engineering students and graduates (Andreatos, 2012). Therefore, developing multimedia material especially mobile multimedia can increase digital communication skills of engineering students.

Developing Mobile Multimedia Learning Instructional Design Principles for Engineering Education

To design and develop teaching and learning activities enhanced by educational technologies, instructional designers and technologist or course instructors should follow proper instructional design principles. Due to the lack of such principles to use mobile multimedia learning for engineering education, a method for developing these principles is proposed.

There are two approaches for using instructional design principles: instructional design as a science and instructional design as a design (Reeves, 2006). As a science, the researchers should use and evaluate these principles in their context through experimental research methods. However, as a design, the researchers should use more flexible and iterative methods like Design-Based Research (DBR) to improve and fit the design principle with the context (Reeves, 2006). Through this method not only a practical teaching or learning problem will be solved, but the design principles will also be improved.

According to DBR method for educational technology, the practical problems should be analyzed first, then a first solution based on existing principles and technological innovations should be prepared. Next, the first solution should be tested and refined through an iterative cycle, and finally, the new design principles will be emerged through the designers' reflection on the first solution during the process (Reeves, 2006).

Although there are no specific instructional design principles for mobile multimedia learning, there are two sources for extracting mobile multimedia instructional design principles which should be considered concurrently: multimedia instructional design principles and mobile learning instruction principles. By combining these two sets, a first version for mobile multimedia learning instructional design principles can be proposed.

Multimedia instructional design principles are relatively clear because many studies have been done in the past three decades. In 2009, Richard E. Mayer extracted twelve multimedia instructional principles from nearly 100 research studies during the past two decades (Sorden, 2012). Unlike multimedia learning, mobile learning instructional design principles are not very clear and the suggested principles are different. Some researchers such as Elias (2011b), Herrington, Herrington, and Mantei (2009), J. Brown and Haag (2014) and Baharom (2013) developed different principles for mobile learning in different contexts using different approaches. It is not surprising because, on one hand, mobile learning is relatively new and the number of research studies about developing a mobile learning instructional design is low while on other hand, mobile learning can be used with different teaching and learning theories.

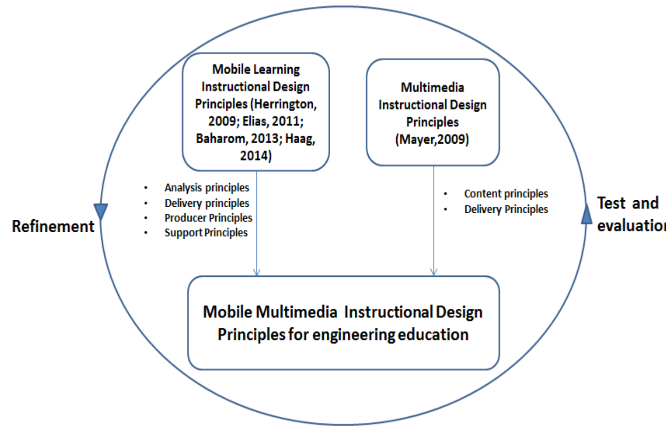

Figure 1: Developing process of instructional design principles for mobile multimedia learning for engineering education

By reviewing and synthesizing existing principles in the realm of multimedia learning and mobile learning (Figure 1.), the following principles for mobile multimedia learning are suggested:

Analysis Principles: The instructional designers should analyze the situation to understand the context. The analysis results help them to understand the problems, limitations and solutions. The experts' suggestions are:

- The context should be understood (Herrington et al., 2009).
- Available technology should be evaluated (Baharom, 2013).

Content Principles: In mobile multimedia learning approach, the content type is multimedia, so the designers should follow multimedia instructional principles (Mayer, 2009) which are summarized as follow:

- Extraneous material should be excluded.
- Essential material should be highlighted.
- Graphics and narration should be combined.
- Words and pictures should be presented at the same time and near each other.
- Words should be presented in conversational style, spoken by a friendly human voice.

Producer Principle: Regarding the unique capabilities of mobile phones in capturing the situation and producing multimedia materials, the mobile learning experts suggest that the multimedia materials should be produced by the learners (J. Brown & Haag, 2014; Elias, 2011a; Herrington et al., 2009). According to the NMC Horizon Report, one of the key trends speed up higher education technology acceptance is the shift from students as consumers to students as creators [35]. Therefore the recommendation is:

- The multimedia materials should be produced by the students using their mobile phones.

Delivery Principles: Regarding the mobile phones' limitations and mobile internet access issues, the content delivery through mobile phones is quite challenging. The experts' recommendations for effective content delivery through mobile phones are:

- Mobile multimedia material should be segmented and presented at the learner's own pace (Mayer, 2009).
- Mobile multimedia materials should be delivered in the simplest possible format (Elias, 2011a).
- Mobile multimedia materials should be packaged in small bits (J. Brown & Haag, 2014; Elias, 2011a).
- The learners' interfaces should be simple (Elias, 2011a).
- Mobile multimedia materials should be delivered through open media sharing sites (Elias, 2011a).
- Solutions should be made for disconnecting situations (J. Brown & Haag, 2014).
- Mobile multimedia materials should support learning in the situation (Elias, 2011a).
- The delivery system should support students to discuss on the learning material together (Elias, 2011a; Herrington et al., 2009; Mayer, 2005).
- Mobile-specific assistive technologies should be used (Baharom, 2013; J. Brown & Haag, 2014; Elias, 2011a).

Support Principles: Regarding the crucial role of the lecturers in the teaching and learning processes and students' responsibilities in creating the multimedia materials, successful mobile learning experience needs their strong support. The experts' suggestion is:

- The lecturers should support students for developing the materials and encourage them towards discussion on the materials (Elias, 2011a).

To develop mobile multimedia instructional design principles for engineering education, practical problems which prevent students to achieve learning objects such as understanding a difficult concept or poor critical thinking should be analyzed by the researcher collaborating with the practitioners such as course instructors and students. Furthermore, students' access to the required technology such as smartphone and high-speed Internet and their acceptance of the mobile multimedia learning should be investigated. Then, a first solution by combining the first version of mobile multimedia instructional design principles, and smartphones' capabilities such as mobile augmented technology which can useful for solving the analyzed problem should be prepared. Next, the solution should be test and refined iteratively based on the students' feedback such as the solution's usability and ease of use and their suggestions for improvement. During this process, not only the problem will be solved, but the design principle for mobile multimedia learning for engineering education , are also developed.

Conclusions

Although mobile multimedia instruction for engineering education is still in its infancy, it will be widely used in the near future. If we believe that multimedia instruction is an effective way of teaching and learning engineering courses, we should migrate from desktop-based multimedia instruction to mobile-based multimedia learning as students are migrating from desktop to mobile and the quality of their mobile phones and mobile internet access are improving continuously. Furthermore, mobile multimedia instruction supports situated multimedia learning which, in turn, helps engineering students to understand difficult concepts and procedures and increases their motivation.

Due to the flexibility of mobile learning and unique characteristics of each contexts, the researchers should use design-based research method to solve their practical problems in teaching or learning engineering courses through mobile multimedia learning and the suggested mobile multimedia instructional design principles can be used as a first version of design principles to start their research. These principles will be improved during research processes that end with a solution for a teaching or learning problem.

References

ABET. (2015, 2015). Criteria for Accrediting Engineering Programs, 2015 – 2016. Retrieved from http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2015-2016/

Álvarez Peñín, P. I., Pérez Morales, M. R., García, D. R. R., Díaz, R. P. G., & Ouirós, J. S. (2004). Multimedia-integrated application for computer-assisted teaching of technical drawing (AIMEC-DT). *Computer Applications in Engineering Education, 12*(2), 136-144. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-33750305256&partnerID=40&md5=db736c09646391b3dc389532c11f1431

Andreatos, A. (2012). Educating the 21st Century's Engineers and IT Professionals. *New Media Communication Skills for Engineers and IT Professionals: Trans-National and Trans-Cultural Demands: Trans-National and Trans-Cultural Demands*, 132.

Baharom, S. (2013). *Designing mobile learning activities in the Malaysian HE context : a social constructivist approach.* (PhD), University of Salford. Retrieved from http://usir.salford.ac.uk/28385/

Benkrid, K., & Clayton, T. (2012). Digital hardware design teaching: an alternative approach. *ACM Transactions on Computing Education (TOCE), 12*(4), 13.

Blau, J. (2011). Germany faces a shortage of engineers. *Spectrum, IEEE, 48*(9), 16-18.

Brown, J., & Haag, J. (2014). Mobile Learning Handbook. Retrieved from https://sites.google.com/a/adlnet.gov/mobile-learning-guide/basics

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Cadoni, E., Botturi, L., & Forni, D. (2008). The TEMAS Multimedia Learning Objects for Civil Engineers. *TechTrends, 52*(5), 17.

Cheng, K.-H., & Tsai, C.-C. (2013). Affordances of augmented reality in science learning: suggestions for future research. *Journal of Science Education and Technology, 22*(4), 449-462.

comScore. (2013). Growth of Video in Germany: PC and Mobile. Retrieved from http://www.comscore.com/Insights/Data-Mine/Growth-of-Video-in-Germany-PC-and-Mobile

comScore. (2014). Major Mobile Milestones in May: Apps Now Drive Half of All Time Spent on Digital. Retrieved from http://www.comscore.com/Insights/Blog/Major-Mobile-Milestones-in-May-Apps-Now-Drive-Half-of-All-Time-Spent-on-Digital#imageview/0/

Elias, T. (2011a). *Universal instructional design principles for mobile learning* (Vol. 12).

Elias, T. (2011b). Universal instructional design principles for mobile learning. *The International Review of Research in Open and Distributed Learning, 12*(2), 143-156.

Felder, R. M. (2012). Engineering Education: a Tale of two paradigms. *Shaking the Foundations of Geoengineering Education, Bryan McCabe (Editor), Marina Pantazidou (Editor), Declan Phillips (Editor)*, 9-14.

Feng, S., Caire, R., Cortazar, B., Turan, M., Wong, A., & Ozcan, A. (2014). Immunochromatographic diagnostic test analysis using Google Glass. *ACS nano, 8*(3), 3069-3079.

Fraile-Ardanuy, J., Garcia-Gutierrez, P., Perez, J. I., & Fraile-Mora, J. J. (2009). Improving understanding of single phase transformer behaviour through a multimedia tool. *International Journal of Electrical Engineering Education, 46*(1), 74-89. Retrieved from <Go to ISI>://WOS:000264970700006

Gardner, A., & Willey, K. (2011). *Peer Feedback–what are students telling each other?* Paper presented at the Proceedings of the 39th SEFI Annual Conference.

Gottfredson, C., & Mosher, B. (2012). Are you meeting all 5 moments of learner need? *Learning Solutions Magazine, June, 18*. Retrieved from http://www.learningsolutionsmag.com/articles/949/

Grasso, D., & Burkins, M. B. (2010). *Holistic engineering education: Beyond technology*: Springer.

Herrington, A., Herrington, J., & Mantei, J. (2009). Design principles for mobile learning.

Jamieson, L., & Lohmann, J. (2012). Innovation with Impact: Creating a Culture for Scholarly and Systematic Innovation in Engineering Education. *Washington DC: American Society for Engineering Education*, 77.

Jayarajah, K., Saat, R. M., & Rauf, R. A. A. (2013). An alternative perspective for Malaysian engineering education: a review from year 2000-2012. *The Malaysian Online Journal of Educational Science*, 1.

Junaidu, S. (2008). Effectiveness of multimedia in learning & teaching data structures online. *Turkish Online Journal of Distance Education, 9*(4), 97-108. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-55049110779&partnerID=40&md5=a24ba0c5f115af8dd51e831d54d42337

Keller, J. M. (2008). First principles of motivation to learn and e3-learning. *Distance Education, 29*(2), 175-185.

Laoui, T., & O'Donoghue, J. (2008). Development of a support environment for first year students taking materials science/engineering. *Research in Science & Technological Education, 26*(1), 93-110.

Lau, H. Y. K., & Mak, K. L. (2004a). The virtual company: a re-configurable open shell for problem-based learning in industrial engineering. *Computers & Industrial Engineering, 47*(2-3), 289-312. doi:10.1016/j.cie.2004.08.002

Lau, H. Y. K., & Mak, K. L. (2004b). The virtual company: A re-configurable open shell for problem-based learning in industrial engineering. *Computers and Industrial Engineering, 47*(2-3), 289-312. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-6344280443&partnerID=40&md5=fd91a0f9709c9216dcda8defbef93a79

Lau, H. Y. K., Mak, K. L., & Ma, H. (2006). IMELS: An e-learning platform for industrial engineering. *Computer Applications in Engineering Education, 14*(1), 53-63. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-33646701673&partnerID=40&md5=3cc04763e362af02a8f600b91c319f2a

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*: Cambridge university press.

Lavy, I., & Bershadsky, I. (2003). Problem posing via "what if not?" strategy in solid geometry—a case study. *The Journal of Mathematical Behavior, 22*(4), 369-387.

Mayer, R. E. (2005). *The Cambridge handbook of multimedia learning*: Cambridge University Press.

Mayer, R. E. (2009). *Multimedia Learning*: Cambridge University Press.

Mejías Borrero, A., & Andújar Márquez, J. M. (2012). A Pilot Study of the Effectiveness of Augmented Reality to Enhance the Use of Remote Labs in Electrical Engineering Education. *Journal of Science Education and Technology, 21*(5), 540-557. doi:10.1007/s10956-011-9345-9

Moore, G., Kerr, R., & Hadgraft, R. (2011). Self-guided Field Trips for Students of Environments. *European Journal of Engineering Education, 36*(2), 107-118. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-79958859901&partnerID=40&md5=2d1f2cc34b3b776d29009a404f159166

Mulop, N., Mohd Yusof, K., & Tasir, Z. (2014, 3-5 April 2014). *The improvement of confidence level of students learning thermodynamics through a multimedia courseware.* Paper presented at the Global Engineering Education Conference (EDUCON), 2014 IEEE.

Munoz-Abella, B., Alvarez-Caldas, C., & Rubio, L. (2011). Computer-Aided Tool for Teaching Mechanical Clutch Systems Design. *Computer Applications in Engineering Education, 19*(3), 493-500. doi:10.1002/cae.20329

National Science Board. (2007). Moving Forward to Improve Engineering Education. Draft Report.

Ozcelik, E., & Acarturk, C. (2011). Reducing the Spatial Distance Between Printed and Online Information Sources by means of Mobile Technology Enhances Learning: Using 2D Barcodes. *Computers and Education, 57*(3), 2077-2085. doi:10.1016/j.compedu.2011.05.019

Patterson, D. A. (2011). Impact of a multimedia laboratory manual: Investigating the influence of student learning styles on laboratory preparation and performance over one semester. *Education for Chemical Engineers, 6*(1), e10-e30. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-78651471534&partnerID=40&md5=758e9d87e19d62dfa1a11a0bbdeef846

Penin, P. I. A., Morales, M. R. P., Garcia, D. R. R., Diaz, R. P. G., & Quiros, J. S. (2004). Multimedia-integrated application for computer-assisted teaching of technical drawing (AIMEC-DT). *Computer Applications in Engineering Education, 12*(2), 136-144. doi:10.1002/cae.20003

Priest, D. J. (2009). *A problem-posing intervention in the development of problem-solving competence of underachieving, middle-year students.* (PhD Thesis), Queensland University of Technology.

Redecker, C. (2008). Review of learning 2.0 practices. *Seville: Institute for Prospective Technological Studies (IPTS)*.

Redecker, C., Ala-Mutka, K., Bacigalupo, M., Ferrari, A., & Punie, Y. (2009). Learning 2.0: The impact of Web 2.0 innovations on education and training in Europe. *Final Report. European Commission-Joint Research Center-Institute for Porspective Technological Studies, Seville*.

Reeves, T. C. (2006). Design research from a technology perspective. *Educational design research, 1*(3), 52-66.

Ryokai, K., & Agogino, A. (2013). Off the Paved Paths: Exploring Nature with a Mobile Augmented Reality Learning Tool. *International Journal of Mobile Human Computer Interaction (IJMHCI), 5*(2), 21-49. doi:10.4018/jmhci.2013040102

Ryokai, K., Agogino, A. M., & Oehlberg, L. (2012). Mobile Learning with the Engineering Pathway Digital Library. *International Journal of Engineering Education, 28*(5), 1119-1126. Retrieved from <Go to ISI>://WOS:000309387300014

Sankar, C. S., Kawulich, B., Clayton, H., & Raju, P. (2010). Developing Leadership Skills in" Introduction to Engineering Courses" through Multi-Media Case Studies. *Journal of STEM Education: Innovations and Research, 11*(3), 34-60.

Sidhu. (2007). Design approaches and comparison of TAPS packages for engineering. *Interactive Technology and Smart Education, 4*(3), 127-137.

Sorden, S. D. (2012). The Cognitive Theory of Multimedia Learning. In B. J. Irby, G. Brown, & S. Jackson (Eds.), *The Handbook of Educational Theories*: Information Age Publishing, Incorporated.

Spinks, N., Silburn, N., & Birchall, D. (2006). Educating engineers for the 21st century: The industry view. *London: The Royal Academy of Engineering*.

YouTube Statistics. (2015). Mobile and Devices. Retrieved from https://www.youtube.com/yt/press/en-GB/statistics.html

Yueh, H. P., Lin, W., Huang, J. Y., & Sheen, H. J. (2012). Effect of student engagement on multimedia-assisted instruction. *Knowledge Management and E-Learning, 4*(3), 346-358. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-84866622518&partnerID=40&md5=08cf7e88b24bbcf4d939caec71b332b4

Yuen, S. T. S., & Naidu, S. (2007). Using multimedia to close the gap between theory and practice in engineering education. *International Journal of Engineering Education, 23*(3), 536-544. Retrieved from <Go to ISI>://WOS:000248391800016