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Technology-Enhanced Learning in Engineering Education

Introduction

With the advanced development in technology, technology has been increasingly employed for teaching and learning in education. It is becoming more economical and convenient particularly among the digital learner of today's generation. Apart from economical and convenience reasons, the use of eLearning has also brought some positive feedbacks from learners who enjoy this alternative learning experience. eLearning is particularly powerful when used in a blended learning environment in conjunction with face-to-face learning.

There are various technology-enhanced learning tools and systems currently in the market, some are developed in-house, some are proprietary developed and some are open-sourced. Among the technology-enhanced learning tools and systems, learning management systems (LMS) have been used extensively in education, and the two most well-known LMS are Moodle and Blackboard. At the University of Hong Kong, Moodle has been adopted as the university LMS, more information can be found on (http://tl.hku.hk/staff/elearning/).

These LMSs allow students to access and download their course materials online. Teachers can opt to conduct quizzes in class and out of class and allow students to submit their assignments via the system, with automatic marking, recording and time-stamping. This helps teachers to facilitate their work and provides instant feedback to students. Furthermore, students can post ideas and information on the discussion forum, where teachers and other peers can respond and further discuss where they left off in class. This creates an interactive channel, where direct feedback between teachers and students are received.

Advantages and Disadvantages of eLearning

This section discusses about the advantages and disadvantages of eLearning from two perspectives: individual learners (students) and educational providers (teachers or tutors) (Roscoe, 2002).

In terms of	**Advantages of eLearning**	**Disadvantages of eLearning**
Individual Learners	• Learning can be conducted at their own convenience (at any time and place). • Learning can also be conducted according to their own preference with respect to their own pace and understanding. • Exposure to learn latest technology and IT skills. • Offer a platform for learners to interact with their peers. • Facilitates better feedback between students and teachers. • Facilitates better interaction between students and teachers.	• Lack of face-to-face interaction (hinder development of face-to-face communication skills). • Not all learners are digital (possess IT skills). • Some learning may not be achievable through eLearning (such as some laboratory sessions due to its expensive and specialized equipments). • Learners heavily relying on the eLearning tool would have an impact on their cognitive engagement with the learning material. • Establishing real-time interaction is hard unless an agreed time is set by the teacher or tutor. • A fully online course provides little opportunity for the students to develop transferable skills such as team work and communications.

In terms of	Advantages of eLearning	Disadvantages of eLearning
Educational Providers	• A course conducted using eLearning can accommodate more students compared to a face-to-face course because of the room capacity. • Supporting extra students would not add too much to the cost. • Teacher can monitor the progress of each student, who enrolled in the course. • Interaction is difficult to achieve in large class, however technologies allow extra interactions through forum and blogs • Improved feedback cycle.	• Time and expense in developing eLearning course. • Teaching a web-based course is more time consuming than a face-to-face course because the number of working hours for a web-based course exceeds a face-to-face course. • The need for extra staff to provide tutorial or technical support for students. • Some teachers are reluctant to changes. • Some teachers are not very digital.

References:

- Chang, L. R, Richardson, J. C., Banky, G. P., Coller, B. D., Jaksa, M. B., Lindsay, E. D., & Maier, H. R. (2011). Practitioner reflections on engineering students' engagement with e-learning. *Advances in Engineering Education Journal*, *2*(3), 16–22.
- Iowa State University. (n.d.). Advantages and disadvantages of eLearning. Retrieved from http://www.dso.iastate.edu/asc/academic/elearner/advantage.html
- Roscoe, J. (2002). The language of e-learning. Retrieved from http://www.heacademy.ac.uk/assets/documents/resources/database/id453_language_of_e-learning.pdf
- Ubell, R. (2000). Engineers turn to e-learning. *Spectrum, IEEE*, *37*(10), 59–63.

Challenges in developing eLearning materials in Engineering Education

The challenges (Gudimetla & Iyers, 2006) in implementing eLearning materials in engineering education include:

(a) Designing instructional materials in order to facilitate learning at all levels.
(b) Teaching technical subjects with the use of common eLearning tools.
(c) Designing instructional materials that cover both depth and breadth as engineering requires a lot of basic theories and knowledge.
(d) For many home-grown technology-enhanced tools, engineering teachers and students often focus too much on the technologies rather than the pedagogy and how the tools can enhance student learning.
(e) Lack of framework or policy that can deliver true dynamic “learning products”
(f) Teachers are not as digital as the students or vice versa.
(g) Teachers are discouraged by changes.
(h) Teachers might be reluctant to incorporate the use of eLearning in teaching because of the extra workload and preparation time needed for the creation of teaching materials.
(i) Implementing eLearning can be at first, time consuming.
(j) Studies have not shown that eLearning has proven to be a huge success in enhancing student learning.
(k) Students have the tendency to just read the “required” materials only. Supplementary materials are often ignored.

References:

- Gudimetla, P., & Iyers, R. M. (2006, December). *The role for e-learning in engineering education: Creating quality support structures to complement traditional learning*. Paper presented at the 2006 AAEE Annual Conference, Auckland, New Zealand.

Tips for Developing and Using Technology-Enhanced Learning Tools

This section explores some of the tips for developing and using technology-enhanced learning tools.

1. Make the tool(s) look modern and user friendly to accommodate our digital generation, as the authenticity of the design makes the tool more engaging.
2. Make the tool(s) self-intuitive so that students put more effort into learning the material rather than learning how to use the program.
3. Consider the reasoning behind the design and why technology is used. You should only use technology if it provides benefits for student learning.
4. Design the learning tool(s) or material(s) to capture the interest of a learner in a way that generates motivation for further learning.
5. Make the content not only informative but also more interactive, so as to prompt learners to reflect on what they have learnt using the tool.
6. Use visual aids to capture and convey the concepts more vividly.
7. Motivate students to access the various online features from time to time so they can get familiarized with the operation of the technological system through class surveys, messages, feedbacks and forums. More often, it is about getting used to the system. If students are familiar with the system, they will find it useful.
8. Develop more interactive online tutorials that prompt students to retry when they answer incorrectly. Providing hints may also encourage students to answer.

References:

- Chang, L. R, Richardson, J. C., Banky, G. P., Coller, B. D., Jaksa, M. B., Lindsay, E. D., & Maier, H. R. (2011). Practitioner reflections on engineering students' engagement with e-learning. *Advances in Engineering Education Journal*, *2*(3), 23–24.
- Gudimetla, P., & Iyers, R. M. (2006, December). *The role for e-learning in engineering education: Creating quality support structures to complement traditional learning*. Paper presented at the 2006 AAEE Annual Conference, Auckland, New Zealand.
- Ubell, R. (2000). Engineers turn to e-learning. *Spectrum, IEEE*, *37*(10), 59–63.

Case studies of eLearning in Engineering Education

Enhancement in student learning experience is achieved through the use of eLearning by offering students an alternative learning experience via improved electronic or technological applications. As a teacher, you can enhance students' learning by initiating certain teaching activities that engages students.

Five Technology-Enhanced Learning Tools in Engineering Education

The following section presents findings on some technology-enhanced learning tools which were developed by engineering practitioners to effectively enhance and stimulate students' learning in engineering.

1. **Video Game-Based Program for Teaching Dynamic Systems and Control (at Northern Illinois University, USA)**

   At Northern Illinois University (Chang et al., 2011), one of the most difficult courses to teach in the Mechanical Engineering curriculum is Dynamic Systems and Control (DS&C) offered to undergraduates. Students find the Laplace-domain mathematics very unnatural and confusing (Coller, 2009) because the mathematics are abstract (Chang et al., 2011).

   In 2008, components of the course such as the assessments and other learning activities were redesigned by incorporating the use of a video game called "EduTorcs". EduTorcs is a video game of a sophisticated vehicle (car or bicycle) simulation that runs in real-time (Coller, 2009). The design of the video game sought to embed real engineering challenges that would require students to devise creative control strategies and deeply explore the dynamics of the vehicles.

   The rationale for introducing the video game to students was to encourage them to learn the material. Problems typically found in the textbook are narrowly focused, oversimplified, and bear little resemblance to the actual engineering practice. However the challenges embedded within the game require real engineering problem solving skills. Students solving the problem need to think, act, and value as engineers. Thus the game is used to create a notably different type of learning environment compared to that of the textbook (Chang et al., 2011; Coller, 2009).

Unlike the traditional method of playing video game (such as using joystick), students have to write algorithms in C++ to control the car or bicycle. Students model the vehicles' dynamics and then design and implement feedback controllers that are sufficiently robust to handle system non-linearities and measurement errors. The algorithms are directly linked to the game at run time. Feedback is given immediately as to whether the algorithms are successful in navigating the car or bicycle under specific scenarios (such as can the algorithm make the car do a sharp turn at 150 mph or make the car crash).

Through teaching DS&C with the video game, students could explore the input/output behavior of the car more deeply, develop more sophisticated steering algorithms, path-following algorithms, and speed control algorithms. By embedding the theory into an engaging context that builds on students' prior knowledge, the game aims to help students clarify abstract computer science concepts. However, the teacher needs to make informed decision on what and how relevant concepts are to be incorporated into the video game (Coller, 2009).

References:

- Chang, L. R, Richardson, J. C., Banky, G. P., Coller, B. D., Jaksa, M. B., Lindsay, E. D., & Maier, H. R. (2011). Practitioner reflections on engineering students' engagement with e-learning. *Advances in Engineering Education Journal*, *2*(3), 1–31.
- Coller, B. D. (2009, June). *Lessons learned from teaching dynamic systems and control with a video game.* Paper presented at the 116th ASEE Annual Conference and Exposition, Austin, TX.
- Coller, B. D. (2010, June). *A video game for teaching dynamic systems and control to mechanical engineering undergraduates.* Paper presented at American Control Conference 2010, Baltimore, MD.

Supplementary Resource:

For your interest, the author has also written another paper exploring the use of teaching dynamics to sophomores using a new video game.

- Coller, B. D. (2012, June). *Preliminary results on using video game in teaching dynamics*. Paper presented at the 119th ASEE Annual Conference and Exposition, San Antonio, TX.

2. **Simulator Software for Experiential Learning in Electrical/Electronic Engineering (at Swinburne University of Technology, Australia)**

The simulator software ("NI Multisim 10") has been used to teach a first year course on electronic systems at Swinburne University of Technology (Chang et al., 2011). The interface lets students wire up any electronic/electrical circuit using the included simulations as though it is like completing the task physically in the laboratory using authentic electronic/electrical components.

In addition, students enrolled to the course will have ownership to a copy of the software, which they can use at their own convenience.

The software has been used as a tool for students in verifying assignment solutions, submitted laboratory preliminary results, answers to tutorial exercises and text book exercises with corresponding simulation in hope of encouraging students' development of critical thinking and analytical skills.

Having this software available for students supports both academic-driven and learner-centered experiential learning, thereby encourages student engagement that leads to deeper levels of understanding and students attaining desirable attributes.

Furthermore it is also encouraging to know that students used the simulator software to check their calculations even though it was not part of their assessment requirement to do so. In another words, the software encourages students to learn on their own by allowing verification of assignment solution at one's convenience.

References:

- Banky, G. P. (2005, September), *Using circuit simulator software in the study of electronic circuit behaviour.* Paper presented at the 2005 AAEE Annual Conference, Sydney, Australia.
- Chang, L. R, Richardson, J. C., Banky, G. P., Coller, B. D., Jaksa, M. B., Lindsay, E. D., & Maier, H. R. (2011). Practitioner reflections on engineering students' engagement with e-learning. *Advances in Engineering Education Journal*, *2*(3), 1–31.

3. **Online Roleplay Simulations for Developing Generic Graduate Attributes and Preparing Engineering Students for Multidisciplinary and International Practice (at the University of Adelaide, Australia)**

The online roleplay simulation ("Mekong eSim") is hosted at the University of Adelaide using the Blackboard LMS (Maier & Baron, 2005). The "Mekong eSim" is an online roleplay simulation set in the Mekong region of South-East Asia which seeks to inform participants of the issues faced in the Mekong region and involve them in the hypothetical management of some of these conflicts (Helpdesk for MyUni, 2013).

The simulation involves 60 – 140 students (second year civil, environmental, and mining engineering students; and students from geography and Asian studies) from a number of universities apart from the University of Adelaide (Maier & Baron, 2005).

It serves to develop students' generic skills and attributes that have been recognized as being important by professional accreditation bodies of engineering degree programs, but are generally difficult to develop in a traditional classroom setting, which includes (a) an understanding of the concept of sustainability; (b) an understanding of the ability to communicate and work in teams; and (c) an understanding of social, cultural, global and environmental responsibilities of engineers (Maier, 2007; Maier, Baron, & McLaughlan, 2007)

The roleplay simulation (Maier & Baron, 2005) involves interactions between multiple learners, who adopt the roles of stakeholders with different responsibilities and point of view. They have to interact with each other about some complex issues without a single correct outcome. The question for discussion is delivered through media announcement ("Mekong TV news"). In response, students attempt to reach a better understanding of the investigated issue or problem through private reflection and sharing of information and opinions. During the process of exploration and integration, students move repeatedly between critical reflection (private) and discourse (shared with community of inquiry).

The roleplay simulation (Maier & Baron, 2005) used in engineering education involves the investigation of an issue through a proposed engineering project. In the context of preparing engineering students for multidisciplinary and international practice, the project should be set in an international context and exploit areas of potential conflict, such as opposing emotions or motives, perpetual differences and/or clashes over limited resources. It is hoped that through this form of activity, it will assist engineering students to see engineering developments from multiple perspectives, and to highlight the social, cultural, global and environmental responsibilities of professional engineers. In addition, students have the opportunity to develop both communication and teamwork skills.

The use of such online environment also enabled students from different geographical regions and disciplinary backgrounds to share the same interactive space by using an online environment. Accessibility along with thoughtful learning design and relevant features shifts student learning from mere involvement to active engagement. A number of online quizzes with deadline were developed in order to motivate students to take initiative in logging into LMS.

References:

- Chang, L. R, Richardson, J. C., Banky, G. P., Coller, B. D., Jaksa, M. B., Lindsay, E. D., & Maier, H. R. (2011). Practitioner reflections on engineering students' engagement with e-learning. *Advances in Engineering Education Journal*, *2*(3), 1–31.
- Helpdesk for MyUni (2013). Mekong eSim. Retrieved from http://www.adelaide.edu.au/myuni/examples/mekong/
- Maier, H. R. (2007). Meeting the challenges of engineering education via online roleplay simulations. *Australasian Journal of Engineering Education*, *13*(1), 31–39.
- Maier, H. R., & Baron, J. (2005, September). *Developing online roleplay simulations for preparing engineering students for multidisciplinary and international practice.* Paper presented at the Proceedings of the 2005 ASEE/AAEE 4th Global Colloquium on Engineering Education.
- Maier, H. R., Baron, J., & McLaughlan, R. G. (2007). Using online roleplay simulations for teaching sustainability principles to engineering students. *International Journal of Engineering Education*, *23*(6), 1162–1171.

4. **Java Applets with Computer Aided Teaching in Geotechnical Engineering (CATIGE) (at the University of Adelaide, Australia)**

   CATIGE Suite (Chang et al., 2011) has been used as a way of deepening undergraduate civil engineering students' engagement in undergoing geotechnical engineering experiments in the laboratory because experiments measuring soil behavior can generally take several hours to perform, as a result students might have the tendency to feel disengaged from the material and learning. Thus educators have attempted to address such factor, which led to the design of CATIGE Suite. CATIGE Suite's design philosophy relates to soil types. The suite contains fifteen separate programs such as Mohr's circle, triaxial test, vertical effective stress calculation, and a geotechnical engineering unit converter. Eight of those programs have been further developed as Java applets.

   CATIGE is used in lectures to assist with the understanding of fundamental geotechnical engineering principles, in practical classes to enhance student engagement and reinforce key learning outcomes, and as an alternative study resource. The software enables students to examine the variables that influence soil behavior, where instant responses and feedbacks are provided. Students engage with the program because it is more responsive compared to laboratory equipment, which facilitates their deeper learning.

References:

- Chang, L. R, Richardson, J. C., Banky, G. P., Coller, B. D., Jaksa, M. B., Lindsay, E. D., & Maier, H. R. (2011). Practitioner reflections on engineering students' engagement with e-learning. *Advances in Engineering Education Journal*, *2*(3), 1–31.
- Jaksa, M. B., Kaggwa, W. S., & Gamble, S. K. (1994, December). *A computer aided teaching suite for geotechnical engineering*. Paper presented at the 1994 AAEE Annual Conference, Sydney, Australia.
- Jaksa, M. B., & Kuo, Y. L. (2009, December). *Java applets in geotechnical engineering.* Paper presented at the 2009 AAEE Annual Conference, Adelaide, Australia.

5. **Remote and Virtual Laboratories (at the University of Melbourne, Australia)**

The remote and virtual laboratories were introduced to third-year engineering students for a laboratory class on data acquisition at the University of Melbourne (Chang et al., 2011). Students in this class were required to calibrate a piezoelectric accelerometer using a Doppler laser. Students were randomly assigned to one of the three modes: (i) a traditional face-to-face laboratory, (ii) an internet-based remote control mode, and (iii) a full virtual simulation of the experiment.

Results gathered suggested that the remote and virtual access mode inherently changes the nature of students' engagement because it not only changes how they learn, but also what they thought they learn. The students in the remote mode were more reflective in their practice. They thought about their data as they gathered it, instead of just writing down the figures. They also proved better at dealing with unexpected results. Apart from the changes in student engagement, students also have changed perceptions of their learning outcomes in the remote and virtual access mode.

References:

- Chang, L. R, Richardson, J. C., Banky, G. P., Coller, B. D., Jaksa, M. B., Lindsay, E. D., & Maier, H. R. (2011). Practitioner reflections on engineering students' engagement with e-learning. *Advances in Engineering Education Journal*, *2*(3), 1–31.
- Lindsay, E. D., & Good, M. C. (2005). Effects of laboratory access modes upon learning outcomes, *IEEE Transactions on Education*, *48*(4), 619–631.

A Computer Aided Drawing Program implemented for Engineering Design and Construction at the University of Adelaide, Australia

The following computer aided drawing software (Willis & Doherty, 2012) is used to create a document on a multi-storey building. An interactive virtual tour of the building and construction was developed based on the technical drawings of the structure. The software allowed the section of the different structural components of the buildings, such as beams and columns, to be displayed in corresponding photographs along with descriptions of details and challenges related to its design and construction. In addition, the tour offered the students the freedom to explore the entire building's construction process and showed examples that accommodate the mechanical and electrical services that affect the arrangement and type of structural elements possible in a building.

Before the face-to-face teaching session, students were required to review the software tool as part of their independent study. This offered students the opportunity to get familiarized with the course content before meeting the teacher and offered students alternative means of learning in which active learning strategies are covered such as situational learning.

A qualitative survey was administered to students regarding the tool. The results showed that students felt that the teaching strategy of using the tool improved their understanding of the intricate relationships between engineering design and construction. In addition, students expressed that the tool improved their appreciation of the inter-disciplinary requirements in engineering practice. They also appreciated the opportunity of flexible learning because it allowed them to study the course materials according to their own pace. They believed that having course materials presented electronically gave them more time to think about the content, thus lecture time could be spent more interactively and effectively instead of just reciting the course materials.

References:

- Willis, C., & Doherty, L. (2012, December). *Improving student interaction using an e-learning tool for engineering design and construction*. Paper presented at the 2012 AAEE Annual Conference, Melbourne, Australia.

A Configurable eLearning System for Industrial Engineering at the University of Hong Kong (HKU)

At the University of Hong Kong (Lau & Mak, 2005), a generic interactive multimedia eLearning system (IMELS) for industrial engineering is created. The following system uses a problem based learning approach and is designed to be a learning program that facilitates users in hosting and delivering knowledge and other web-based materials. The purpose of designing a system that incorporates a problem based learning approach is: (i) to revitalize the teaching and learning process of industrial engineering and (ii) to create a learning platform that transcends the limits of space and time. The content covered in the system includes “a multimedia introduction to industrial engineering”, “an electronics knowledgebase” and “a platform that facilitates interactive problem-based learning through real-case problems”. The major objectives of the system are: (i) to use the computer-based materials along with traditional teaching; (ii) to use the system as an “up-to-date repository” for practicing experts in the field; and (iii) to update existing materials and to build up new information.

The design of the IMELS also offers the following features: (i) the IMELS is generic such that the computer based material is able to integrate perfectly with the existing curricula. The content and resources developed will also be used to support the teaching of courses within the department including developing video lectures, laboratory sessions, and tutorials to replace or act as a complementary to the existing material; and (ii) the system has the ability to continue developing in the ever evolving industrial and business sector. The system should be reconfigurable without requiring major effort in redesigning it. However activities like withdrawing information and creating new case problems need to be taken care of.

The design of the IMELS in the following study has focused its attention on the “architecture of the virtual company” that supports the problem-based learning model and facilitates teachers in tracking students’ learning activities and facilitates dynamic reconfiguration.

References:

- Lau, H. Y. K., & Mak, K. L. (2005). A configurable e-learning system for industrial engineering. *International Journal of Engineering Education (IJEE)*, *21*(2), 262–276.

Evaluating Learning Experiences in Virtual Laboratory Training through Student Perceptions: A Case Study in Electrical and Electronic Engineering at the University of Hong Kong (HKU)

In this ever evolving world of information technology, virtual laboratory (Chan & Fok, 2009) has started to revolutionize engineering education. The development of virtual laboratory has generated discussion about the fundamental learning outcomes of laboratory training courses and has sparked an interest in the consequent changes to the students' learning experiences.

The following study (Chan & Fok, 2009) is an initial phase of a research agenda that focused on investigating the effectiveness of virtual laboratories in the Department of Electrical and Electronic Engineering (EEE) at HKU. The long term goals of the agenda are to explore how effective virtual EEE laboratories are (in terms of: (i) delivering specific learning outcomes; (ii) engaging and motivating students; and (iii) engaging and motivating teachers) and to discover whether the laboratories can ultimately become a replacement of the traditional laboratory training by providing an equivalent and comparable learning experience for students.

In engineering, problem solving, designing, creating and building are critical elements that students need to acquire. In order for students to acquire such elements, theoretical knowledge (through lectures and tutorials) and practical experience (hands-on laboratory sessions) is a must for their education. Laboratory training is absolutely vital in engineering and in most science-related disciplines. It facilitates students to understand and reinforce their theoretical concepts and targets a range of learning outcomes (including experiential learning process that cannot be delivered through lectures and tutorials).

Although there seems to be general consensus that laboratories are indeed necessary, most studies on engineering education tend to focus on curriculum design and innovative in-class or laboratory learning activities and technologies. Therefore the following investigation explores students' perception about laboratories.

The investigation is conducted through the use of a survey that explores students' perceptions in an intensive one-month compulsory summer EEE laboratory training session (that uses both traditional hands-on (3/4) and virtual laboratory (1/4) session). The survey targeted second year students majoring in a three-year honours degree in Computer Science, Industrial, and Electrical Engineering, who are enrolled into the EEE laboratory training session. It contains both open-ended and close-ended questions that explored elements evaluating student perceptions of traditional and virtual laboratories, and on the usage of laboratories. Results were collected from 50 students (13 females and 37 males), with forty-six local students, one international student and two mainland Chinese students, and one who did not indicate either attributes.

Results revealed that students' attitude towards virtual laboratories were generally well-received. However they felt that the traditional laboratories were easier to operate and understand, flexible to use in relation to time and place, and satisfying compared to virtual laboratories. They felt that virtual laboratories are more suited for senior students than first years. In general, students tend to prefer longer laboratory hours for traditional laboratory session rather than virtual laboratory session. Some students also perceived the use of both traditional laboratory and virtual laboratory to be equally important thus the virtual laboratory may not yet be a replacement of the traditional laboratory. However virtual laboratories can serve a supplementary role in addition to the traditional laboratories by facilitating enhanced study outside of laboratory hours.

References:

- **Chan, C. K. Y.,** & Fok, W. W. T. (2009). Evaluating learning experiences in virtual laboratory training through student perceptions: A case study in electrical and electronic engineering at the University of Hong Kong. *Special Issue: Learning Technologies in Engineering Education: The Journal of the Higher Education Academy, Engineering Subject Centre, 4*(2), 70–75.

A Comparison of MCQ Assessment Delivery Methods for Student Engagement and Interaction Used as an In-Class Formative Assessment at the University of Hong Kong (HKU)

In engineering education, Multiple Choice Questions (MCQs) are often widely used for both formative and summative assessment. MCQs are popular to use among engineering practitioners because: (i) they are relatively less time consuming to design; (ii) to answer; (iii) to correct; (iv) to provide feedback; and (v) to administer. They have high reliability, validity, and manageability. Such characteristics along with changes in the higher education environment such as large class size, curriculum changes towards student-centered approach, and the possibility of administering MCQs through the use of technology-enhanced tools are also elements constituting its popularity.

The following study conducted by Chan, Tam, and Li (2011) was designed to compare three different methods of delivering MCQs namely pen & paper, online eLearning (or WebCT Online), and Clickers in terms of their effectiveness on student engagement and interaction used as an in-class formative assessment. The results were also compared to classes not using any in-class formative assessment.

The study was conducted on an elective course (ELEC2601: Human Computer Interaction) offered to Year 2 and 3 students. For each delivery methods, sets of ten non-credit bearing MCQs were written to assess students' knowledge on the topics. The investigation was conducted through administering surveys after the end of each class to examine student perceptions on these different assessment methods. Teachers were also part of the investigation as they were interviewed to gather their experiences and attitudes towards these MCQ methods in relation to the pedagogy used, the learning outcomes, and their perception of students' reaction towards these methods. Apart from the surveys and interviews, an external participant was invited to oversee and evaluate the student's and teacher's attitude during the assessment.

Results were analyzed with respect to these aspects (i) effectiveness of these learning tools and students' engagement towards these tools; (ii) student-to-student interaction (in-class and out of class); (iii) student-to-teacher interaction (in-class); (iv) critical thinking and classroom behavior; (v) assessment; and (vi) overall satisfaction.

Results revealed that among the learning tools introduced, students agreed that Clickers (69%) were highly effective as a learning tool for teaching and learning followed by Web CT online MCQs (63%). However unexpectedly, students also agreed to a large extent that pen & paper (63%) also had such an effect. Regarding the level of engagement, students were neutral about WebCT online MCQs and pen & paper. In fact, 25% of the students disagreed that WebCT online MCQs could improve engagement.

82% of the students agreed that Clickers increased student-to-student interaction in class; however 56% of them were neutral about whether its use in class improves student-to-student interaction out of class. Students who agreed that WebCT online MCQs and pen & paper increased student-to-student interaction in class are only 44% and 37% respectively. Even fewer students agreed on its increase in interaction out of class.

Both Clickers and WebCT online MCQs helped students feel more connected to the teacher. 44% of the students agreed that they seemed to know the teacher better as a result of the in class interaction with the use of these respective tools compared to a class conducted without the use of these tools. For pen & paper, there were only 25%. In terms of increased interaction and discussion with the use of Clickers, students (69%) felt that they themselves achieved increased interaction and discussion using Clickers, whereas 81% of the students felt that the teacher achieved that.

In addition, using Clickers and WebCT online MCQs enhanced students' critical thinking in classroom and improved their attention during lecture. Half of the students agreed that Clickers increased their willingness to ask questions in class. While fewer than 20% agreed for WebCT online MCQs and pen & paper. Students agreed that Clickers (69%) and WebCT online MCQs (62%) motivated them to question and monitor their own understanding of the concepts during class. Although there are slightly more than half of the students who agreed that Clickers helped improved their attention in class similar to that of WebCT online MCQs, for pen & paper the reception was fairly low in comparison to the two previous methods.

Regarding assessment, 50% of the students were neutral about using Clickers, WebCT online MCQs, or pen & paper as an assessable in-class exercise. Based on the findings, students would prefer answering the assessment using pen & paper (60%) more than Clickers (44%) and WebCT online MCQs (57%) if the in-class exercise was assessed because pen & paper may seem more formal.

Among the methods introduced students ranked Clickers to be their first choice followed by WebCT online MCQs and pen & paper. Students (51%) were both satisfied and extremely satisfied with the use of Clickers and pen & paper. However for WebCT online MCQs the satisfaction rate is lower.

Apart from students' responses, results from teachers' interviews indicate that teachers found that students paid more attention when Clickers were used and were certainly more engaged in the class. Although the person overseeing the assessment process noticed that there was minimal interaction among students about the discussion of the questions because the teachers did not encourage students to interact or discuss the questions, however, students did interact among each other during the distribution of the Clicker.

Even though the MCQ designed targets lower-order cognitive level knowledge, the external participant agreed that students were all engaged during these non-credit bearing MCQ sessions. However with WebCT, teachers found little interaction in class as the opportunity of giving and receiving feedback is not as good as that of Clickers. In fact, the use of WebCT as an in-class formative assessment seems to have negative effects as observed by both the teacher and the participant.

References:

- **Chan, C. K. Y.**, Tam, V. W. L., & Li, C. Y. V. (2011). A comparison of MCQ assessment delivery methods for student engagement and interaction used as an in-class formative assessment. In Julie Johnson, *International Journal of Electrical Engineering Education, 48*(3), 323–337.