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BRIDGING THE GAP BETWEEN THEORIES AND APPLICATIONS IN TEACHING ENGINEERING MECHANICS SUBJECTS VIA MOBILE LAB AND FLIPPED CLASSROOM

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***Abstract:** There is a paradigm shift taking place in the academy, in which the focus is moving from faculty and their teaching to learners and their learning. Efforts to improve learner learning include a variety of innovative pedagogical approaches (such as cooperative learning, problem-based learning, and technology-enhanced education, etc.). Most engineering lecturers who teach engineering mechanics subjects, specifically Statics and Dynamics courses are used to teach this subject in lecture form only and no labs are included. This research however suggests a teaching technique that could reduce or eliminate the gap between theories and applications in teaching engineering mechanics subjects through achieving a lecture/lab hybrid classroom environment where mobile lab illustration along with flipped classroom method (Hybrid Class) are implemented for more learners' engagement (students-cantered learning) and better teaching technique that covers both visual/practical and auditory/theory learning styles. In the flipped classroom, the lecturer is available to learners at home through videos or internet based lectures and class time is used to complete homework-like assignments. By moving instruction to the home and homework to the class, learners are given more one-on-one time with their lecturer to work through their assignments and the role of the academic staff was flipped from a lecturer to an instructor. During class time, mobile lab toolkits are used to further illustrate the main concepts of the given subject and the instructor asks the learners to start an experiment by discussing with their peers and make a prediction of the outcome of that experiment. Results showed a positive effect on the learners' performance and competency after implementing this teaching and learning technique. It has also shown that a higher level of problem difficulty can be presented during the class to encourage a mutual group discussion and prepare the learner to problem-based learning (PBL) teaching approach.*

***Keywords:** Mobile Lab, Flipped Classroom, Hybrid Class, Blended Learning, Students Cantered Learning*

Introduction

When engineering lecturers think the best, most important way to improve their teaching is by developing their content knowledge, they end up with sophisticated levels of knowledge, but they have only simplistic instructional methods to convey that material. To imagine that content matters more than process is to imagine that the car is more important than the road. Both are essential. What we teach and how we teach it are inextricably linked and very much dependent on one another (Kim, C. & Thomas, 2008; Kim, C. & Linder, 2009; Jiusto, 2006). For instance, obtaining a conceptual and deep understanding of engineering mechanics subjects has proven to be one of the most critical challenges that facing engineering learners. Many research studies have shown that the misunderstood conceptions about the nature of forces, vectors, kinetics and kinematics, which many learners have, are very hard to overcome. This is mainly due to the way the usual combination of lecture and laboratory is practiced in most engineering disciplines, specifically engineering mechanics. Lecture and lab are seldom taught in the same class and, therefore, different topics are covered in two separate classes resulting an obvious gap between theories taught during lectures and its real applications (Bofah et al., 2010). Many programs now incorporate mobile and virtual labs into their instruction to increase learner access to equipment, greater flexibility in lab scheduling, a wider range of possible assignments or activities, and enhanced opportunities for collaboration among learners. Increasing the amount of time that learners have access to lab equipment can result in greater time-on-task per learner; increased access may also refer to the types of equipment on which learners may work. Either of these scenarios is likely to result in more and/or more varied learning. When labs are accessed online, learners can potentially be engaged in learning at any time and from anywhere they have Internet access, as opposed to hands-on activities that rely on the times that campus buildings are open and staff members are available. This increased access opens the door to activities that may take longer than a typical class meeting time or multi-part assignments that require learners to use equipment for several short periods over the span of a week or more, both of which pose logistical barriers in a hands-on environment. Finally, there may be enhanced opportunities for learner collaboration when labs are accessed online, by removing the same-time same place constraints posed by traditional work groups. These efforts could be strengthened by greater collaboration with colleagues in open education, cognitive science, and ethnography who are breaking important ground independently at present. The goals of such work include exploring the diversity of learning styles of engineering undergraduates, experimenting with the use of multimedia materials, and developing a theoretical framework for curriculum design. The results of this work will allow us to more effectively educate the engineer of the future (Ramsden et al., 2003; Nehm et al., 2014).

The current work, however, attempts to answer the following question:

1- How to implement the flipped classroom in any engineering class?

2- How to promote self-directed model of learning engineering subjects?

3- How to bridge or eliminate the gap between theories and applications in teaching engineering mechanics subjects using mobile lab toolkits?

Literature Review

There is a problem in the way the usual combination of lecture and laboratory is practiced in most engineering and science disciplines everywhere. Lecture and lab are seldom taught in the same class and, therefore, different topics are covered in two separate classes (Kim, C. et al. & Thomas, 2008; Kim, C. & Linder et al., 2009). Often, lecture and lab are taught by different instructors. Consequently, the intended learning reinforcement by active experimentation of lectured abstract concept is not realized. Theories and applications have been divided; simulations and implementations, alienated. There is prodigious need for lecture/lab hybrid class that unifies two components together, and equally high is the demand of experiential learning in which introduction of theories and their experiences are instant and dynamic. Behind this persistent disunity between lecture and lab, there is a practical reason: the daunting task of bringing lab into class (Bofah et al., 2010).

Therefore, acquiring a conceptual understanding of mechanics has proven to be one of the most difficult challenges faced by learners. Studies by many different researchers have shown that the misleading conceptions about the nature of force and motion, which many learners have, are extremely hard to overcome (Ramsden et al., 2003; Nehm, R., 2014; Marshall, D., 2004; NRC, 2012). These strong beliefs and intuitions about common physical phenomena are derived from personal experiences and affect learners' interpretations of the material presented in a physics course. Research has shown that traditional instruction does very little change learners' common-sense beliefs (Maloney et al., 2009). To overcome this challenge, researcher have reported an alternative practical approach for teaching engineering mechanics subjects more effectively (Bernhard, 2000; Hake, 1998).

Bernhard et al. (2000) have implemented Microcomputer based laboratories (MBL) which have successfully been used to promote conceptual change in mechanics. In MBL-labs learners do real experiments and taking advantage of the real-time display of the experimental results facilitates conceptual change by the computer. Thus learners' alternative conceptions can successfully be addressed. Because data are quickly taken and displayed, learners can easily examine the consequences of a large number of changes in experimental conditions during a short period of time. The learners spend a large portion of their laboratory time observing physical phenomena and interpreting, discussing and analyzing data with their peers. The MBL context adds capacity and flexibility that, to be exploited requires the lab to be re-conceptualized, giving learners more opportunity to explore and learn through investigations (Hake et al., 1998).
In the course laboratory the learners again gain real-world experience. Most labs are of a discovery type and done co-operatively in groups of 3-4 learners. The learners are usually asked to start an experiment by discussing with their peers and make a prediction of the outcome of that experiment. Thus learners' preconceptions relevant to the phenomenon being studied are elicited. Secondly they perform the experiment and are asked to compare outcome and prediction. If the outcome and prediction do not agree, they are asked to reflect on their observations. This challenges learners' personal theories and helps them in their process of substituting their naive belief with a more "scientific" one. If outcome and prediction do agree this strengthens beliefs who are in agreement or close to the scientifically accepted ones (Bernhard et al., 2007; Baillie et al., 2009)

Why Flipped Classrooms are Significant?
These short lectures encourage a self-directed model of learning, allowing learners to select lessons to watch and to move through them at their own pace, stopping and replaying a recording as needed to ensure understanding of the content. At the same time, the format encourages instructors to be concise in their presentations. A flipped classroom can focus on a single important point, providing a self-study opportunity for foundational concepts and those that are difficult to understand (Page et al., 2015). Flipped classrooms can be used with any pedagogical approach to explain basic concepts and thus free some portion of classroom time for problem solving and application. In this way, they provide particular support for the flipped class model, where online lectures are viewed outside of class and in-class time is reserved for review and activities so that instructors are available to assist when necessary. The perception of one-on-

one interaction that flipped classrooms provide to viewers can create a sense of instructor presence, as if he or she is speaking directly to the student, something that may otherwise be limited in large lecture halls, crowded classrooms, or online courses (McLaughlin et al., 2014).

How Flipped Classrooms Promote Active Learning?

If flipped classrooms are used to teach basic concepts outside the classroom, this allows for an increase in active learning during class time, which has been shown to enhance student learning. The role of the teacher in face-to-face settings changes from a presenter to a learning coach. Classroom time is spent talking with the learners and working alongside them. Teachers who implement flipped classrooms for the delivery of direct instruction can instead spend a typical class period assessing mastery, providing remediation as necessary, answering questions, working with small groups, and guiding the learning of each student individually (Bergmann et al., 2012). Learners have noted the benefits of this. In informal interviews, learners noted that, "It gives you an opportunity to talk to the teacher about problems you are struggling with," and "You can get more help on the assignments at school instead of struggling with them on your own (Schultz et al. 2014). Not only do teachers gain the benefits of increased interaction with their learners, student to student interaction is also increased. In this environment teachers see their learners relying more on each other to develop new understandings and to expand their learning. Class time can be used for team laboratory exercises, problem-based learning, fieldwork, research, and experiential learning opportunities. The ways in which flipped classrooms can help free up class time for the increased social construction of knowledge are endless. The main objective of this research is to reduce or eliminate the gap between theory and application of engineering mechanics subjects through achieving a lecture/lab hybrid classroom environment where mobile lab illustration along with flipped classroom (Hybrid Class) method are presenter for more learners' engagement and better teaching technique that covers both visual/practical and auditory/theory learning styles.

Prepared Materials and Methods

Equipment or Facilities

Equipment for Flipped Classroom

Video Equipment (a USB camera, Canon 70D)
Audio Equipment (Blue Snowball)
Power Video Editing PC (CPU: AMD R7 1700, Graphics Card: GTX 1050 Ti, Motherboard: MSI B350 PC Mate, RAM: 16 GB DDR4-3000, Storage 1: 525GB Crucial MX300 SSD, Storage 2: 2 TB hard drive, Power Supply: EVGA GQ 650W, CPU Cooler: NH-U12S SE-AM4, Case: Fractal Define R5, and Operating System: Windows 10)

Equipment for Mobile Lab

A mobile trolley with set of Engineering Science kits
Four Work Panels (one for the lecturer to demonstrate the concepts and three for learners to apply the learnt concept and theory via practicing it simultaneously).

Creating Effective Groups of Learners (Teams)

Group studies is though beneficial and an interesting way of learning; but the positive impact of group learning solely depends upon the created groups. Studies show that the optimum number of learners in a group is between 3 and 4 members (Baillie et al., 2009). Therefore, a team of 3 or 4 members is recommended; however, in our class case, I have almost 40 learners, so for example if I couldn't manage to split them into two main groups 20x20, then I have to create a bigger group in which the maximum number of members should not exceed 5. The criteria that might be used to form an effective group are:

- Level of academic achievement; heterogeneous distribution
- Learning style or personality types
- Ethnic or racial backgrounds or where their family lives
- Gender; if possible we assign more than one female in one group otherwise, more attention is required on that group
- Flipped classrooms

It is always logic that class time would be better invested by guiding knowledge and providing feedback to learners rather than delivering direct instruction. It is also allowing the lecturer/instructor to practice the simple but effective design of a typical class session with active learning (the Book-ends division of a class session). Therefore, the following strategies will be adopted to implement this teaching method:

a) Learners will be assigned a "homework" of watching video or slide lectures and reading materials relevant to the next day's class that have already been uploaded via 'ULearn system'. During class time, lecturer will highlight and discuss the most significant and fundamental concepts that might not be sufficiently covered via video or slides lecture where practical demonstration and learners' interaction are essential. Learners on the other hand will practice what they have learned through their homework of reading and listening along with the highlighted practical session by solving some selected problems that cover the course outcomes appropriately.

b) Considering the learners are divided in to certain number of groups, each group will be assigned to solve different real applications problems and to share their answer as a video presentation uploaded through ULearn system.

c) Reflection activities will be built to get learners think about what they learned, how it will help them, its relevance, and more every time they watch a video.

Mobile Lab

Most engineering subjects are used to be taught with lectures only and no labs are included. For that, we engaged the demonstration and teaching equipment/kits (see Figure 1) in the class where learner can have immediate feedback by applying the knowledge and theories learnt during and before the class time. This teaching practice is also known as "mobile lab". Using mobile lab, the learners gain real-world experience. The mobile lab tools are discovery type and was conducted co-operatively in groups of 3-4 learners. The learners are usually asked to start an experiment by discussing with their peers and make a prediction of the outcome of that experiment. Thus learners' preconceptions relevant to the phenomenon being studied are elicited. Secondly they perform the experiment and are asked to compare outcome and prediction. If the outcome and prediction do not agree, they will be asked to reflect on their observations.

Figure 1. Mobile Trolley (Lab) With A Complete Set of Engineering Science Kit to Demonstrate the Most Important Concepts in Engineering Mechanics Such as Equilibrium of Rigid Body, Equilibrium of Forces, Etc. at the Classroom.

Assessment of the Mobile Lab

Both formative and summative assessments of the learners' performance in the course will be conducted. Statics and Dynamics course has five assessment components: quizzes, assignments, two tests, reflection and final exam. The learners are required to take 8 quizzes spread over the semester (the average of five quizzes will be considered), all together contributing 5% to the total course grade, two assignments 5% each and two mid-term exam (tests) with 15% each one, finally the comprehensive final exam with 50% as shown Figure 2. Learners will be asked to submit their self-reflection report at the mid and end of the semester. In order to profoundly assess the relatively new teaching feature of Mobile Lab, we have also designed three independent surveys over the semester for the Statics and Dynamics course. So far, only the first survey was conducted by the instructor of the course, while the other two will be conducted at the end of the semester in collaboration with an evaluation specialist. The first survey aimed to measure mainly the acceptance of the learners on implementing mobile lab in S&D class. It also attempted to see how learners actually experienced the experiential learning the mobile lab pedagogy tried to achieve. On the other hand, the second survey will be the result of the instructor's observation of learners' grades, stimulation, and attitude of the course. The last survey, will be conducted at the end of May semester 2017. It was designed by a specialist for more comprehensive look on the impact of Mobile Lab.

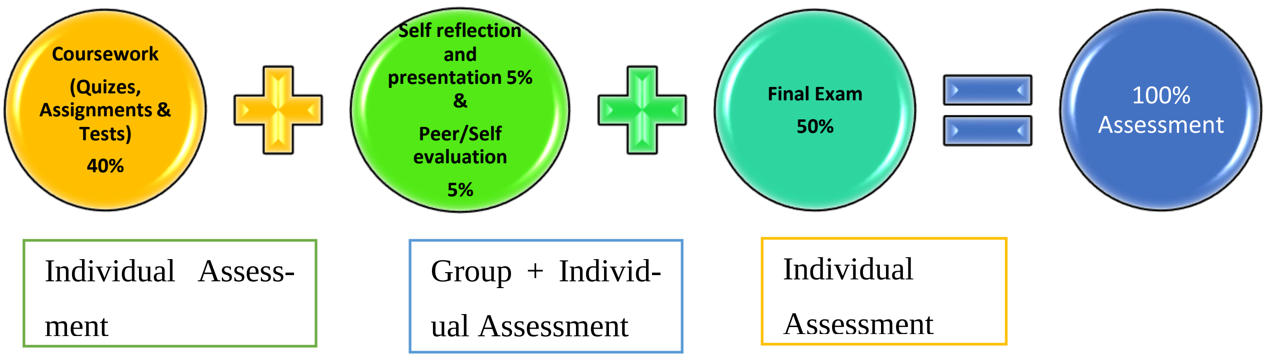

Figure 2. Formative and Summative Assessments of The Learners' Performance in The Course

Results and Discussions

Survey on Acceptance and Learning Experience of Hybrid Class

There are 53 learners registered in the Statics and Dynamics class in May 2017 semester. We placed the following five questions for the learners to respond. First three questions were for the general acceptance measurement, the fourth one for the hands-on experience, and the last one for the problems they met and the improvement they wanted to see. The questionnaire was emailed to the learners and 38 responded. The questions and analysis briefs are as follows:

1) What did you like most of the Flipped classroom /Lab (hybrid class)?
- Over half the learners liked the practical sense of the class. About 40% of the learners were impressed more on the technology enabled new learning environment. Overall 90% of the learners were favorable to mobile lab class.

2) Do you like to have more hybrid classes?
- In this question, the answer was just one common, “yes.” Because of the new class, new technology, or any other reason, they liked the mobile lab class and they wanted more.

3) In addition to S&D class., which course(s) would be most benefited by the hybrid class?
- Most could suggest the expansion of the benefit in S&D class. And the experience of the mobile lab into other courses that they have yet to take. However, solid mechanics and fluid mechanics courses received most votes in the suggestion.

4) What did you learn most from the hybrid class?
-In this questionnaire we wanted to measure the pedagogical proof of flipped classroom /Lab (Hybrid Class). The response was very strong in the benefit of the hybrid class in the connection of theory and practical application. At the same time, learners’ appreciation of technology in teaching was also noted, which could be taken as acceptance of the mobile studio class.
5) What improvement did you feel we have to make for better hybrid class?

-There were many problems in the first semester of mobile studio. Hardware connection and occasional malfunction problems were persistent through the semester. Also, the existing class time of one and half hours were usually short for theory explanation, circuit implementation, and testing and measurement using mobile studio. These problems were addressed for better arrangement and improvement for the next mobile studio class. In summary, in the spring 2005 launch of mobile studio class in Network Analysis, amid problems and difficulties, learners very favourably accepted the new learning environment, and experienced and benefited from the experiential learning phase of conceptualization to active experimentation.

Observation of Learner Performance and Behaviour Under Mobile Lab

Instructor’s observation and analysis of May semester 2017 hybrid class on S&D course are directed to the performance and attitude of the learners in the class compared with those of Jan. 2017 class. This survey will be presented by the end of the current semester with the following survey questions:

Q- Using the Hybrid Class increased my:
1) Understanding of the lecture
2) Ability to apply the theory
3) Knowledge of the subject matter
4) Attention to the lecture

5) Interest in the subject matter
6) Class attendance
7) Motivation in class
8) Participation in class
9) Interaction with the instructor
10) Interaction with other learners

Conclusions

Implementation of flipped classroom /lab (hybrid classroom) has shown positive effect on the learners' performance and competency. Enhanced teaching plan/ framework with integrated self-efficacy lab based lecture for better integrations between theories learnt and its practical applications. It has also showed that higher level of problem difficulty can be presented during the class to encourage a mutual group discussion and prepare the learner to problem-based learning (PBL) teaching approach.

In summary, hybrid classroom launched in May semester 2017, among problems and difficulties, learners have favorably accepted the new learning environment, and experienced and benefited from the experiential learning phase of conceptualization to active experimentation.

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