Innovative Teaching and Learning Tools for Foundation in Engineering Education

Christopher M. K. Chew, F. L. Ooi, Mushtak Al- Atabi, Satesh Namasivayam
Taylor's University
Correspondent Author E-mail: christophercmk@gmail.com

Abstract
Students in Malaysia who aspire to pursue a degree in engineering have the option of enrolling in either a specific foundation programme or a generic pre-university programme, which while offering more flexibility, does not offer the focus of an engineering specific foundation programme. This paper outlines the design of a new foundation programme that is aimed at preparing year 11 students to smoothly transit into an engineering programme of their choice. This programme has three main features, firstly, it is project-based and designed according to the CDIO Framework, secondly, the theory part of the programme is delivered using technology, namely iBook and MOOCs, and thirdly it has and eXtreme Learning Process (XLP). The surveys done to assess the trial runs of the XLP and the iBook indicate that students found the methodology to be both useful and interesting. The first batch of students will join in July 2013 and more data will be available by then.

Introduction

A high demand for a specific-for-engineering foundation programme is present in the Malaysian education sector. Students who are interested to pursue an engineering degree from an early age are keen on taking up an engineering specific foundation level education as opposed to universal pre-university as the appropriate preparation course for an engineering degree. Its foundation programme is the platform to inculcate the essential and necessary skills that are needed for the transition to an engineering degree. In current pre-university courses, there are a lack of emphasis on engineering related skills and knowledge that would serve as the basis to the start of an excellent engineering degree. Hands-on practical work are only limited to laboratory exercises is a common practice for pre-university programmes in Malaysia.

The main research area is the study of the effectiveness and suitability of iBooks, MOOC, XLP and Project-based Learning in conducting Foundation in Engineering classes that would provide a stepping stone with the necessary skills and knowledge towards inculcating an engineering degree. In the Taylor's University Foundation in Engineering course, emphasis would be placed on three main areas namely interactive enhanced learning, hands-on applications and uncovering potential. The Foundation in Engineering would be carried out with the relevant tools to enhance the learning experience as well as develop skills such as team work, communication, leadership and other soft skills which are crucial skills for the development of an engineering student. These areas are done by using four main applications namely Massive Open Online Course (MOOC), iBook, Extreme Learning Process (XLP) and Project-based Learning with the CDIO framework. The use of this application would assist students in completing the Foundation in Engineering programme outcome in a short period of time but with maximum level of achievement.

The effectiveness of project-based learning in higher education has been investigated in the past such as by de los Rios et. al. where investigations into the last two decades worth of project-based learning was conducted in the Technical University of Madrid [1]. There is also similar work that was done in the University of Tokyo where Otake et. al. conducted a study on autonomous collaborative environments for project-based learning [2]. Furthermore, studies

were conducted at the National University of Malaysia (UKM) which investigates education for sustainable development utilizing project-based learning methodologies and the inculcation of soft skills through project-based learning [3] [4]. There are also previous studies on the implementation of technological advancements for teaching and learning in higher education in the United Kingdom [5].

This paper reports on the foundation in engineering programme structure and design as well the preliminary findings of the surveys conducted and the future plans.

Methodology

The Foundation in Engineering is a course that is catered specifically as a pre-training to students who are wishing to pursue an engineering degree after their pre-university studies. The course structure and delivery method of the Foundation in Engineering would tackle the discipline specific knowledge of an engineering course as well as the essential skills needed to be an engineer.

The Foundation in Engineering would be delivered by focusing on three main areas namely autonomous learning using technology, hands-on project based learning, and workshops to uncover student potential. These three main areas would prepare students for an engineering degree and would be the essential foundational knowledge that would create a training platform before entering an engineering degree.

The parameters would be tackled using a myriad of delivery methods, autonomous learning using technology would be carried out by the use of education on iPad. Each student in the Foundation in Engineering would be issued an iPad with preloaded iBooks that would replace conventional textbooks for all the subjects in the Foundation in Engineering. Furthermore, subjects offered on the Foundation in Engineering would also be offered on a Massive Open Online Course (MOOC) to provide autonomous learning to students.

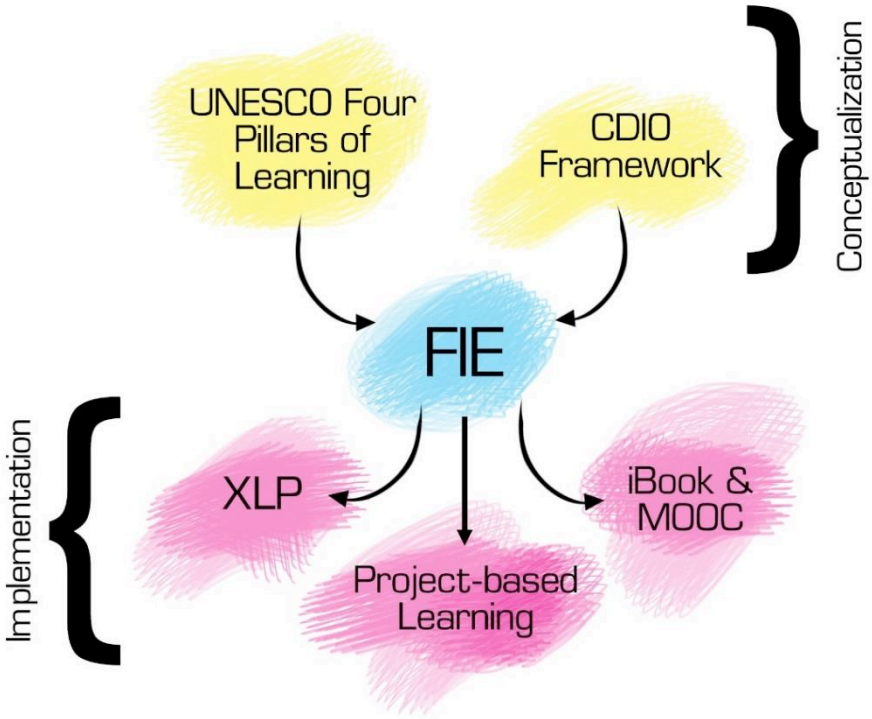

Figure 1: Foundation in Engineering conceptualization and implementation.

Figure 1 depicts the conceptualization and implementation of the Foundation in Engineering programme which is designed using the UNESCO Four Pillars of Learning and the CDIO Framework and implemented using tools such as XLP, Project-based learning, iBooks and MOOC. The UNESCO Four Pillars of Learning places emphasis on a holistic approach towards education, and the CDIO Framework would form the basis for cultivating systematic engineering problem-solving skills. The programme outcomes for Taylor's University's Foundation in Engineering programme are developed based on the goals set out by UNESCO and CDIO [6].

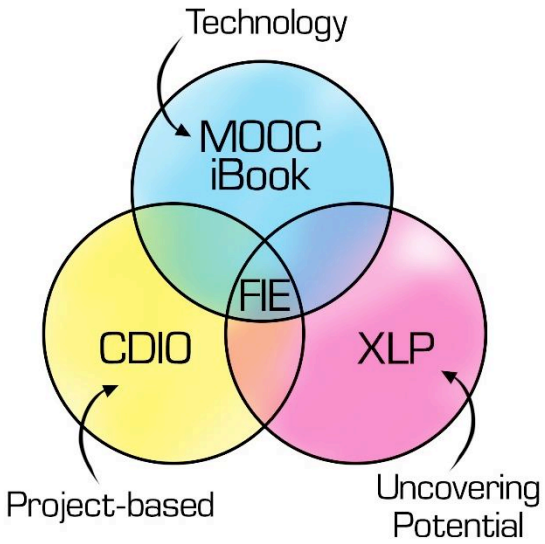

Figure 2: The main parameters encompassing the Foundation in Engineering delivery methodology

Education on iBook & Massive Open Online Course (MOOC)

The iBook is an interactive platform for the teaching and learning of the Foundation in Engineering. It has the capabilities of replacing physical textbooks and also enhancing them with superior functions that surpass those of regular eBooks and pdf files which are merely digitalized versions of the original book. The iBook would be a useful tool for the education sector as it has the capabilities of making the process of learning interactive and interesting. Among the functions and capabilities of an iBook that would be integrated into the Foundation in Engineering include:

- Improved graphics and visualizations to express various ideas. Users can touch and expand diagrams, pictures and text for better understanding.
- 3D-diagrams that can enhance the visualization of various engineering drawings and systems.
- Embedded educational videos that does not require streaming and can be accessed without an internet connection.
- Tutorials, questions and problems posed in the iBook with immediate answer checking capabilities.
- Ability to conduct search for meaning, definitions, or additional information by highlighting words in the iBook.
- Embedment of any functioning webpage into the iBook to enable users to access various applications such as social media, discussion threads, forums and groups to improve lecturer-student interactivity.

- Note taking and highlighting that can be converted immediately into study cards to assist revision sessions.
- All textbooks located in one place with the relevant notes without having the necessity of physical books.
- Ability to continuously update the iBook throughout the course of teaching and learning through feedback and suggestions from various users.

The iBook can be a tool of teaching and learning that is used and synchronized between various institutions across the globe. Updates and changes can be made by various parties with Apple's iBook Author software and sharing is easy and convenient. Authors may consists of educators and students alike with contribution from both parties to make the teaching and learning process fun, informative and engaging. As no actual publication is required, amendments can be made without the need of reprinting the entire book. All users can receive new updates easily without making any new purchases.

The Foundation in Engineering is targeted to expand into a MOOC platform whereby the various modules in the Programme would be offered to students from all over the world, free of charge, through an open online environment. The objective for the Foundation in Engineering Programme is to prepare students for the world and university life by using the latest technologies and innovations to aid students' learning process. The expansion into MOOC would break the geographical and financial barriers and allow this course to be accessible from all around the world. Furthermore with all the materials for the Foundation in Engineering being developed using latest technologies and embracing innovation, conducting the Foundation in Engineering online would be a natural progression. The development of the Programme textbooks entirely on the iBook platform would make it portable through the digital world.

In addition, having an open source education platform would see input from students and academicians from all around the world and allow the programme to progressively improve over time. The Foundation in Engineering would be the first foundation programme in Malaysia to be offered online for free. As a developing nation, Malaysia is still facing issues where citizens in various states of Malaysia have limited or no access to tertiary education. By having the Foundation in Engineering offered as an MOOC, steps are taken to hopefully affect a change in the current state of education in Malaysia. With better education comes improved living conditions and a better future for the nation.

Table 1: Implementation plan for iBook.

Proposed iBook Strategy and Its Objective(s)
• Autonomous learning capitalizing on the latest technology • Improve interactivity between lecturer-student and student-student • Enhance interest of learning in students
Planning Assumptions and Decisions
Students taking the Foundation in Engineering course would be supplied with and iPad preloaded with subject iBook for respective subjects. It is assumed that students are technology savvy and would be able to use the iPad and relevant applications without hassle.
Ownership/Stakeholders
Lecturers and tutors of respective subjects would develop the iBook and produce relevant materials for the students. Authors and Taylor's University would claim ownership on the iBooks used.
Work Breakdown Structure
In order to ensure the classes for Foundation in Engineering are conducted smoothly, the following tasks are to be completed: • Update individual subject syllabus to reflect newest information and knowledge

• Ensure all written materials are incorporated into the iBook • Staff and developers to be supplied necessary resources such as iPad and other related items in order to develop materials
Timeline
Phase 1 to complete two iBooks for the subject of PHY3015 Physics 1 and ENG3014 Engineering Innovation, Civilization and the Future of Humankind by July 2013. Phase 2 to complete a further two iBooks for the subject of PHY3025 Physics 2 and ENG3024 Engineering Design and Innovation by December 2013.
Cost and Resources Required
Each faculty member of the Foundation in Engineering Programme to be supplied with an iPad and necessary tools amounting to approximately RM 20 000.00. Additionally, each enrolling student would be supplied with an iPad costing RM 1 500.00 each.
Means of Monitoring and Control
A student feedback would be conducted after each chapter of the iBook for each subject to gain student input and comments.
Impact Assessment
Student academic performance would be key indicator. Additionally, survey would be conducted at the end of the semester to gain insightful assessment on the successful usage of the iBook.

Project Based Learning and CDIO

The Foundation in Engineering is the first and only programme at the foundation level to be constructed using the CDIO framework. Hence there will be heavy emphasis on project-based learning in the subjects that is conducted through the Conceive, Design, Implement and Operate mindset. With students being exposed to hands-on project work at a foundation level, students would be well prepared to make the transition to a degree level without significant culture shock. Project-based learning would be carried out each of the two semesters in the Foundation in Engineering with students having to complete a project in one of the modules offered in each semester.

With a dedicated module to teaching Engineering Design, the foundation students would be able to learn and apply CDIO before any other Engineering students. This guided and assessed project-based learning would be the platform for students to work in teams and think innovatively. Projects completed in the semester would be presented at an Engineering Fair, Hackerspace or a similar event to have industrial experts, academicians and the public assess and comment on the projects. This sharing of knowledge and guidance from external sources would serve as a guideline and benchmark in creating and producing projects of commercialization quality. Furthermore, the input from various parties would assist students in improving themselves at an early level. This would also serve as an experience pot for students to gain valuable insights into the needs and demands of the society.

Two project-centered subjects would be taught to students in two semesters. These subjects are:

- ENG 3014 Engineering Innovation, Civilization and the Future of Humankind
- ENG 3024 Engineering Design and Innovation

The two subjects would take on a CDIO approach in the learning process, in which students would have to work in groups to solve engineering challenges in the form of a project or product. Students would be assessed on their project work and be given an opportunity to present and justify their case to members of the public comprising mainly of industrial experts and academicians. This project-based learning approach is designed to train the students in

critical thinking, decision making techniques, leadership, teamwork and communication. The skills would be essential in progressing forward with an engineering degree.

Table 2: Implementation plan for Project Based Learning

Proposed Project Based Learning Strategy and Its Objective(s)
• Provide practical hands-on application knowledge and experience to students. • Expose students to working in teams on solving challenges • Allow students freedom for creativity, expression and management
Planning Assumptions and Decisions
Students taking the Foundation in Engineering course would be taking an engineering design module in each respective semester, ENG3014 Engineering Innovation, Civilization and the Future of Humankind in semester 1 and ENG3024 Engineering Design and Innovation in semester 2. A project addressing an engineering challenge would have to be completed in the 18 weeks of a semester.
Ownership/Stakeholders
Module coordinators would propose project titles for teams of students. Students would have ownership towards their own projects.
Work Breakdown Structure
In order to ensure the classes for Foundation in Engineering are conducted smoothly, the following tasks are to be completed: • Project planning to be conducted by module coordinator, prior to the start of the semester • Resources and materials need to be ready for student use • Project supervisors consisting of individuals who are motivated are to be assigned to randomly drawn teams of students • A clear objective and goal of the project has to be outlined • Assessment methods and breakdowns to be ready at the start of the module
Timeline
Students would have 18 weeks to conceive, design, implement and operate an engineering product. Students would need to have a presentation and demonstration at the end of the 18 weeks.
Cost and Resources Required
Cost and materials required for the construction of the project would vary according to project assignment.
Means of Monitoring and Control
A faculty member would be assigned to each team as a project supervisor, to check weekly meeting logs, project proposal, and project report. Project supervisors would also provide advice and guidance to the teams of students.
Impact Assessment
Students would be evaluated at the end of the semester by the module coordinator and appropriate marks would be awarded. Additionally, external parties would be invited as part of the evaluation team, comprising of engineering industrial personnel and academicians, to provide feedback and rate the performance of the students.

Extreme Learning Process (XLP)

The Extreme Learning Process (XLP) is an intensive 4-days educational workshop that is conducted to allow participants to gain extensive knowledge of a particular system or topic of study. The XLP would be used as an educational tool to conduct and teach the Foundation in Engineering. XLP is conducted on the pretense of an intensive 96-hours continuous learning process with participants receiving minimal break time. Furthermore, participants would be *quarantined,* and cut off from any distractions or disturbances to ensure a completely focused environment to be able to absorb vast amounts of knowledge in a short period of time. The XLP is conducted based on a scenario of a project that participants would have to conceive, design, implement and operate within the 4-days. Due to the intensive nature of the program, all participants are required to declare if they have any health issues or are under medication.

In addition, periodical testing for blood glucose level, hand-eye coordination and speech are carried out to ensure that participants are still mentally and physically capable of carrying out the entire XLP.
XLP is a platform for education that can be conducted across institutions without boundaries. Taylor's University Malaysia conducted a joint XLP session with Tsing Hua University, Beijing to a very successful outcome. The main objective of that particular XLP session that was conducted was to introduce programming and robotics to students while enhancing the participants' presentation and business skills. The scenario in the aforementioned session was an oil and gas company seeking to use robotics to discover and recover natural gasses underneath the ocean bed, off the coast of a fictional island.

Over the course of the XLP, participants were given problems and challenges that were commonly faced in real life situations and were forced into thinking and coming up with an immediate solution. Furthermore, discussion sessions were conducted with the participants from Tsing Hua University to share knowledge and findings from the course of the session. At the end of the 4-day session, participants are required to produce a complete lab scale robot with a simulated environment and a business plan to convince venture capitalists to invest.
The process was well received by the participants who had zero knowledge in the field that was pursued. The intensive course has exposed the participants to the relevant areas with a majority finding the session to be beneficial in future endeavors. This favorable response from the participants indicates a potential in using the XLP as a tool for education by utilizing it as a medium for instruction in various subjects. Among the benefits of the XLP workshop include:

- Ability to shorten the learning period from an average of 4 weeks to 4 days without compromising the learning outcomes of a topic.
- Enhanced concentration and the ability to focus from participants with no distractions and disturbances.
- Improve teamwork and communication skills between participants as strict and short deadlines forces them to work together.
- Improve time management skills and prioritizing by participants in order to achieve deadlines on a short notice.
- Communication and collaboration between participants of a foreign country improve the understanding of different learning cultures and requires participants to overcome communication barriers.

Table 3: Implementation plan for Extreme Learning Process (XLP)

Proposed Extreme Learning Process (XLP) Strategy and Its Objective(s)
• Achievement of Foundation in Engineering programme outcomes in a short period of time • Enhance students communication and teamworking skills • Uncover student potential as leaders • Instil a systematic problem solving approach in time constraint challenges
Planning Assumptions and Decisions
Each subject in the Foundation in Engineering is targeted to have one session of XLP per semester in the respective area of learning. The XLP would help enhance students' knowledge in a particular topic and serves as a platform for students to excel in soft skills.
Ownership/Stakeholders
Lecturers and tutors of respective subjects would plan and organize each individual XLP. Student would complete a project in the short workshop period and ownership of the project would belong to both lecturer and student.
Work Breakdown Structure
In order to ensure the classes for Foundation in Engineering are conducted smoothly, the following tasks are to be completed:

• Timeline for XLP to be scattered across the 18 weeks from subject to subject • Planning of XLP to be done prior to the start of the semester • Topics that are complex are to be identified as topics to be addressed in the XLP
Timeline
Each XLP session is expected to be run for 4 days. With 4 subjects, the XLP should be run at a 4 week interval from each XLP.
Cost and Resources Required
Each XLP would have varied cost and expenses depending on the project and topic addressed. An estimate expenditure of RM 1 500.00 to RM 4 000.00 per XLP is expected.
Means of Monitoring and Control
Facilitators and lecturers to be present throughout the XLP to monitor students' progress and provide necessary feedback and guidance. Students are required to give a presentation on progress update at the end of each day.
Impact Assessment
Student would be assessed at the end of the XLP and appropriate marks to be awarded. A pre- and post- survey would be conducted to gain insight into the progress of the student.

Results

A sample of nineteen participating students in the Extreme Learning Process (XLP) was interviewed in a written survey before and after the XLP in relevant areas. The participants were required to rate from a scale of 1 to 5 in the various parameters their personal evaluation of themselves. 1 would be the lowest and 5 would be the highest competency. Participants were assessed one hour before the XLP and one hour after the XLP with a four day duration of the XLP as an interval. The results were computed by comparing the before and after personal evaluation of each participant to determine an improvement, decline or equivalent in their personal skills.

Table 4: A comparison of the level of knowledge gained before and after the XLP

Parameter	Improvement		Equivalent		Decrease	
	No. of Students	Percent (%)	No. of Students	Percent (%)	No. of Students	Percent (%)
Knowledge in Mathematics and Science	9	47.4	10	52.6	0	0.0
Problem solving skills	13	68.4	6	31.6	0	0.0
Ability to discover new knowledge	11	57.9	8	42.1	0	0.0
Holistic thinking capabilities	12	63.2	7	36.8	0	0.0
Decision making capabilities	11	57.9	8	42.1	0	0.0
Leadership skills	11	57.9	7	36.8	1	5.3
Awareness of social responsibility of engineers	9	50.0	9	50.0	0	0.0
Teamwork skills	11	57.9	8	42.1	0	0.0
Writing and oral communication skills	11	57.9	8	42.1	0	0.0
Presentation skills	12	63.2	6	31.5	1	5.3
Global understanding and perspective	12	63.2	6	31.5	1	5.3
Ability to set goals and achieve them	15	78.9	4	21.1	0	0.0
Ability to manage projects and achieve objectives on time and within budget	15	78.9	4	21.1	0	0.0

From Table 4, it can be observed that each parameter has seen an average of 60% improvement by the participants. This is a significant improvement on a participants skills in a mere four day session. The development of each skill in a short period of time has shown the effectiveness of the XLP in developing student's potential.

Table 5: Foundation in Engineering Programme Outcomes

PO 1	Appreciate the role engineering, innovation and technology play in developing and sustaining human civilization.
PO 2	Exhibit thinking skills and triumphing over challenges abilities.
PO 3	Communicate effectively.
PO 4	Effectively search for information from different sources including online sources and reference them properly.
PO 5	Apply team strategies and contribute positively to team objectives.
PO 6	Use science and mathematics to describe real world phenomena.
PO 7	Analyze various challenges using the Scientific Method.
PO 8	Conceive, Design, Implement and Operate simple engineering systems and products.

With the use of the XLP, it is clearly observed that the use of the XLP would be a tool for the students to achieve the Programme Outcomes. Programme Outcome 2, 3, 5, 6, and 8 can be achieved by using the XLP in a short period of time. Student's learning experience and achievement would be enhanced by using the XLP as an educational teaching tool.

A survey was conducted on 24 random students and academicians on the comparison between iBook and PowerPoint. Participants of the survey were shown a PowerPoint slide of a topic in a Foundation in Science Physics class that is currently being used by lecturers. The same content was converted to iBook format and shown to the participants. An evaluation of various comparative parameters of the two materials were done by the participants.

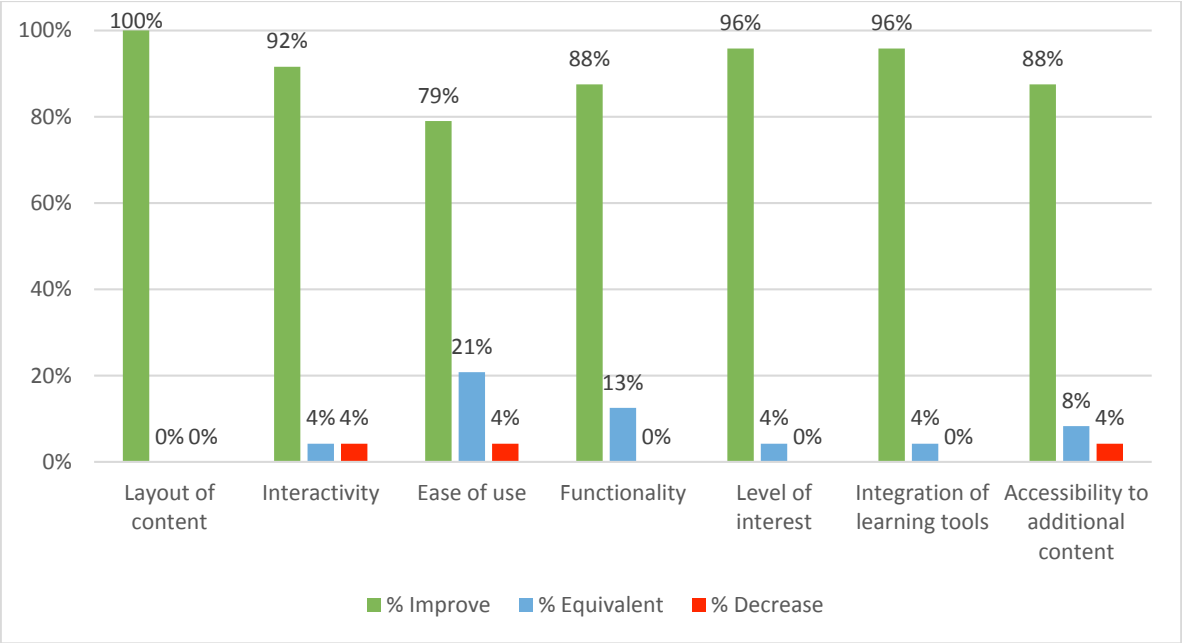

Figure 3: A comparison between various parameters of the iBook versus PowerPoint

From Figure 3, it can be observed that an overwhelming number of participants have responded positively towards the teaching material in the form of the iBook as opposed to the PowerPoint format. The favorable results are an indication that the iBook is a format that would be well

received in terms of approach and functionality. An additional question of "would the iBook improve the overall student learning experience" received a "yes" from 23 of the 24 respondents. Additional elaboration by the participants showed that the iBook is well received due to its interactive content, portability and functionality.

Table 6: Teaching tools and programme outcome achievement mapping

Programme Outcomes	iBook	XLP	PrBL
1	X		X
2	X	X	X
3		X	
4	X		X
5		X	X
6	X		X
7	X		X
8		X	X

Referring to Table 6, it can be inferred that these tools are essential in the achievement of the Programme Outcomes of the Foundation in Engineering Programme.

Conclusion

The various tools described in this paper would achieve the Foundation in Engineering Programme Outcomes that prepares students for an Engineering degree. Prospective engineering students would find the transition from foundation studies to tertiary education less jarring through the implementation of the discussed tools in the Foundation in Engineering programme.

References

[1] I. de los Ríos, A. Cazorla, J. M. Díaz-Puente and J. L. Yagüe, "Project–based learning in engineering higher education: two decades of teaching competences in real environments," *Procedia Social and Behavioral Sciences,* vol. 2, pp. 1368-1378, 2010.

[2] M. Otake, R. Fukano, S. Sako, M. Sugi, K. Kotani, J. Hayashi, H. Noguchi, R. Yoneda, K. Taura, N. Otsu and T. Sato, "Autonomous collaborative environment for project-based learning," *Robotics and Autonomous Systems,* vol. 57, pp. 134-138, 2009.

[3] R. M. Yasin and S. Rahman, "Problem Oriented Project Based Learning (POPBL) in Promoting Education for Sustainable Development," *Procedia Social and Behavioral Sciences,* vol. 15, pp. 289-293, 2011.

[4] F. Musa, N. Mufti, R. Abdul Latiff and M. Mohamed Amin, "Project-based learning (PjBL): inculcating soft skills in 21st Century Workplace," *Procedia - Social and Behavioral Sciences,* vol. 59, pp. 565-573, 2012.

[5] A. Kukulska-Hulme, "How should the higher education workforce adapt to advancements in technology for teaching and learning?," *Internet and Higher Education,* vol. 15, pp. 247-254, 2012.

[6] M. Al-Atabi, "Inculcating CDIO Skills at Pre-Degree Level," in *International CDIO Conference 2012*, Brisbane, Australia, 2012.