DOI: 10.15415/jotitt.2015.31004

Investigating the Effect of Theoretical and Laboratory Teaching on the Students' Academic Performance in Mechanical Engineering

SANDEEP CHOWDHRY

School of Engineering, Edinburgh Napier University, Scotland, U.K.

Email: S.Chowdhry@napier.ac.uk

Received: December 18, 2014| Revised: February 24, 2015|Accepted: May 20, 2015

Published Online: June 29, 2015

Abstract: In order to improve the students' learning experience in the Mechanical Engineering (ME) modules, a problem based learning (PBL) approach is used and the learning activities are designed to provide students with an opportunity to learn theory and perform the experiments to develop a better understanding of the subject. The aim of this action research is to investigate the effect of the theoretical and laboratory based instructions in the Engineering Applications module on the students' academic performance. The sample is composed of 106 students from Edinburgh Napier University (ENU) in Scotland. The data is comprised of the marks obtained by the students in the summative design assessment, based on the theoretical studies and the two online quizzes based on the laboratory experiments. The results show that the module's instructions are mostly focused on the experimental studies which indicates that the experimental studies are not supporting the theoretical studies. It illustrates that the theoretical studies and the experimental studies indirectly support each other. It also shows that the students are not provided with an adequate opportunities to develop the engineering application skills. This implies a need to constructively align such modules, in order to improve the student's learning experience. The concept mapping tools can be used to evaluate the effectiveness of the teaching practices on the students learning experience. The learning activities design should take into consideration the learning styles of the students to encourage them to actively participate in the PBL environment. In addition, the educational institutions should provide support to the academics to improve their facilitation skills in the PBL environment. A suggestion for further research is made to evaluate the effectiveness of the theoretical and experimental teaching instructions based on the Bloom's Taxonomy on the students learning experience.

Keywords : PBL, instruction design, learning styles

Journal on Today's Ideas – Tomorrow's Technologies, Vol. 3, No. 1, June 2015 pp. 53–72

CHITKARA UNIVERSITY

1. INTRODUCTION

The engineering teachers should create a Constructively Aligned (Biggs, J., Tang,C., 2007) environment which is encouraging and supportive of students engaging in the appropriate and necessary mental activity to construct their own learning and to take the responsibility of their own learning. In addition, the Constructive Alignment encourages,- 1) clarity in the design of the curriculum,- 2) transparency in the links between the learning and assessment,- 3) facilitates deep learning leading to improved quality of learning and graduates in engineering profession (Houghton, Dr. W., 2004). Kverenbekk's (2012) research findings state that for an effective learning to take place there should be an equilibrium between the theory and practice. The process of practical application of the theoretical concepts provides students with an opportunity to actively participate in the learning, leading to an increase in the efficiency of the learning. Felder and Silverman (1988) state that learning styles of most engineering students are visual, sensing, inductive and active, and some of the most creative students are global; most engineering education is auditory, abstract (intuitive), deductive, passive, and sequential. These mismatches lead to poor student performance, professional frustration, and a loss to society of many potentially excellent engineers. In order to improve the students learning experience in the engineering modules, the lecturers should adopt different teaching techniques. For instance, introducing practical experience in the university courses will improve the students' achievement of the learning outcomes (Dumitrescu et al., 2009;Standal et al., 2013). Similarly, the goal oriented method and practice in experimental teaching leads to the formation of student-centered, teacher-led teaching pattern in the teaching process (Ming-chao & Jing, 2012). However, Güneşet al.'s,- (2011) research findings state that teachers do not have knowledge about all teaching techniques such as constructivist, problem based learning, cooperative learning, expedition-observation techniques, experimentation techniques. As a result, teachers need to undergo continuous professional development (CPD), education research, sharing best practices and professional associations (Fink, D.,Ambrose,S.,Wheeler, 2005) to keep themselves informed about the latest knowledge in the field.

The previous year's student's feedback indicates that students are having difficulties in studying this module. At the moment, no previous information or literature is available on the effectiveness of the learning and teaching activities in the current module. Therefore, the aim of this study is to investigate the effectiveness of the theoretical and laboratory teaching on the students' academic performance, and to improve the students' learning experience in the module. In particular, the current study has two objectives: (1) to evaluate the students' learning experience in the theoretical and experimental studies, (2) to provide suggestions on the teaching and learning activities, in order to improve the students learning experience in the module.

2. BACKGROUND

The present ME module is taught in 3rd year at Scottish Credit and Qualification Framework (SQCF) level 9 over the period of one trimester (15 weeks). The students studying this module are pursuing the bachelor's degree in different engineering fields such as Renewal Energy, Electronics, Mechanical, Materials, Product Design and Engineering Management at ENU. Most of the students have progressed from 2nd year at ENU and some are direct entry international students. The students have varied learning skills and different learning requirements. The module is aimed at teaching engineering application skills by using Computer Aided Engineering (CAD) software, performing engineering design calculations manually and on the software, and performing laboratory experiments. The blended online teaching methodology is adopted in a PBL environment to teach the module.

The module is assessed for the theoretical study with the help of a summative design assessment on engineering design problem to evaluate the students understanding of the theoretical engineering design calculations and the CAD skills. The summative assessment coursework carries a weightage of 50% of the overall module marks. The students' understanding of laboratory experiments is evaluated with two online multiple choice quizzes. Students attempt the quizzes on the virtual learning environment (VLE) in the presence of the lecturer. Each quiz has 10 multiple choice questions and carries a weightage of 25% of the overall module marks. This action research is useful for the engineering institutes in enhancing the students' learning experience on similar modules by improving the teaching practices and by using an effective assessment.

Figure 1 shows the concept map of the teaching and learning activities in the module. For instance, tutor role is to conduct the design lectures, CAD lectures and helping students' in performing laboratory experiments, and providing study support to the students'. Second, there are different types of learning resources such as library, VLE, study notes and CAD screencasts. Third, students' tasks involves performing engineering calculations, create CAD assembly and complete the laboratory experiments. Therefore, the learning and teaching activities are aligned with the goal of achieving the module's learning outcomes of students' ability 1) to perform engineering calculations, 2) producing engineering drawing, and 3) measuring strain in the engineering structures.

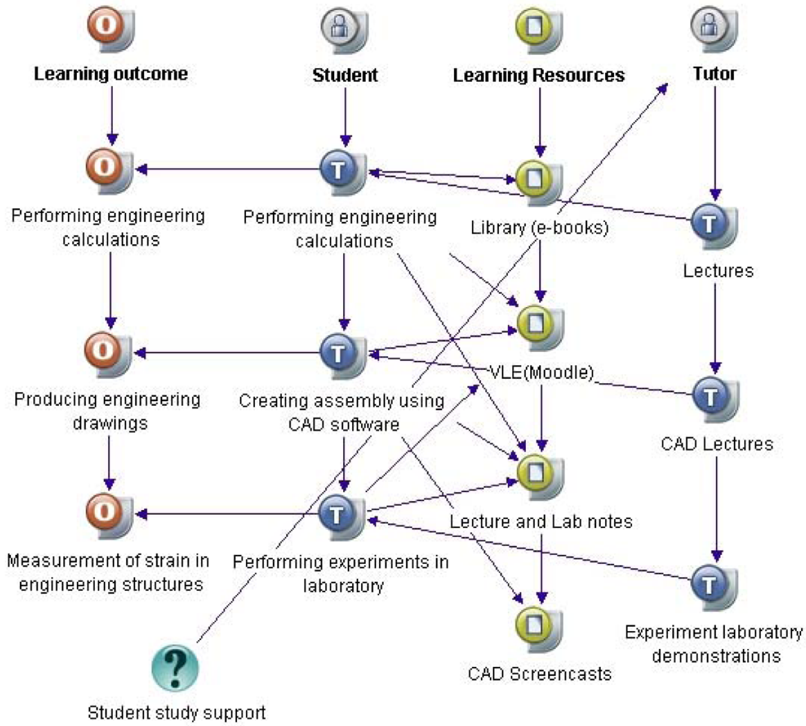

Figure 1 : Teaching and learning activities in the module.

3. RESEARCH METHODOLOGY

The study was carried out in the year 2013-14. Both the quantitative and qualitative data are used in the analysis. The qualitative data comprises of anonymous online students' feedback on the module's learning experience. The quantitative data comprises of the summative design assessment based on the theoretical studies and the two online multiple choice quizzes based on the experimental studies. The quantitative data is anonymised and replaced by numbers for the data analysis. The summative design assessment was marked manually by the module leader and the online quizzes marks were collected from the Moodle (VLE). The study sample is comprised of the aforementioned ME module with 106 students.

The qualitative data analysis has involved careful reading of the students' feedback responses to identify the main themes. Secondly, the information is assembled around specific themes and categorising information in specific terms. Finally, decisions and the drawing of conclusions related to the RQ has been performed. Similarly, the quantitative data has been analysed using the bar graphs, box plots have been used to compare the quizzes and the scatter plots with the best fit line has been used to find the correlation between the variables. The final marks obtained by the students in quiz-1 and quiz-2 are right skewed. The data transformation is ineffective in achieving the data normality. Therefore, it has been decided to perform non-parametric test for the correlation analysis. To statistically determine the correlation between the variables, Spearman's rank-order correlation coefficient has been calculated. The statistical software SPSS 20.0 (academic version) is used to perform the data analysis with alpha (α=0.05).This quantitative study has been carried with quizzes marks as an independent variable and the design assessment marks as a dependent variable. The quizzes marks and the Design assessment marks are the scale variables.

3.1 Research Design

The research work presented in this paper has been driven by mixed research method approach with two qualitative and one quantitative research questions. The results from qualitative and quantitative study have been used to improve the students learning experience in the theoretical and the experimental studies.

The first research question (RQ) is:

RQ1: Does the qualitative students' feedback provide an evidence that the module's teaching instructions are helping them in the experimental and the theoretical studies?

The aim of this research question is to find whether the laboratory experiments experience is helping the students' with the engineering design calculations. To answer this research question, the qualitative analysis of the students' online feedback response data has been performed.

RQ2: Whether the experimental studies supports the theoretical studies?

The aim of this RQ is to find whether the laboratory experiments are complementing the theoretical engineering design tasks. In order to answer this RQ, the quantitative data of the final marks obtained by the students in both the online quizzes and the summative design assessment have been analysed for variation and correlation in two stages. In the first stage,

RQ2.1: Is there a variation within the final marks obtained by the students in the theoretical studies and the experimental studies?

The aim of this research question is to compare the online quizzes and the design assessment coursework for their easiness or difficulty based on the marks obtained by the students. It has been assumed that the greater variation in the marks mean that students have difficulty in understanding and performing the task. To answer this research question, the final marks obtained by the students in the online quizzes and the design assessment have been analysed graphically using the bar graphs and the box plot and the variation in the marks has been compared using their standard deviation (SD) values.

In the second stage,

RQ2.2 Is there a correlation between the final marks obtained by the students in the theoretical studies and the experimental studies?

The aim of this research question is to find whether the online quizzes and the design assessment coursework have been correlated with each other. It has been assumed that positive correlation between the quizzes marks and the design assessment marks mean that the experimental studies and the theoretical studies supports each other. To answer this research question, the final marks obtained by the students in the online quizzes and the design assessment coursework have been analysed graphically using the scatter plot and statistically by computing the spearman's correlation coefficient value. Accordingly, the RQ was specified which is as follows:

The null hypothesis (H_0) has been that there is no significant correlation at the 0.05 alpha level, between the final marks obtained by the students in the online quizzes and the design report coursework.

H_0: There is a no correlation between the final marks obtained by the students in the quiz-1 and the design assessment coursework.

H_0: There is a no correlation between the final marks obtained by the students in the quiz-2 and the design assessment coursework.

The alternative hypothesis (H_1) has been that there is a significant correlation at the 0.05 alpha level, between the final marks obtained by the students in the online quizzes and the design assessment coursework.

H_1: There is a correlation between the final marks obtained by the students in the quiz-1 and the design assessment coursework.

H_1: There is a no correlation between the final marks obtained by the students in the quiz-2 and the design assessment coursework.

RQ3: Whether students are given opportunities to develop engineering application skills?

The aim of this RQ is to find whether the students have been provided with the learning opportunities to develop the engineering application skills by bringing together the knowledge of the theoretical and the experimental studies. In order to answer this RQ, the evaluation criteria of the summative design assessment

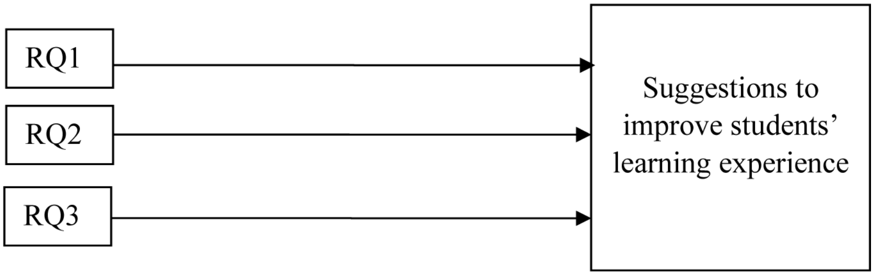

Figure 2: Research model.

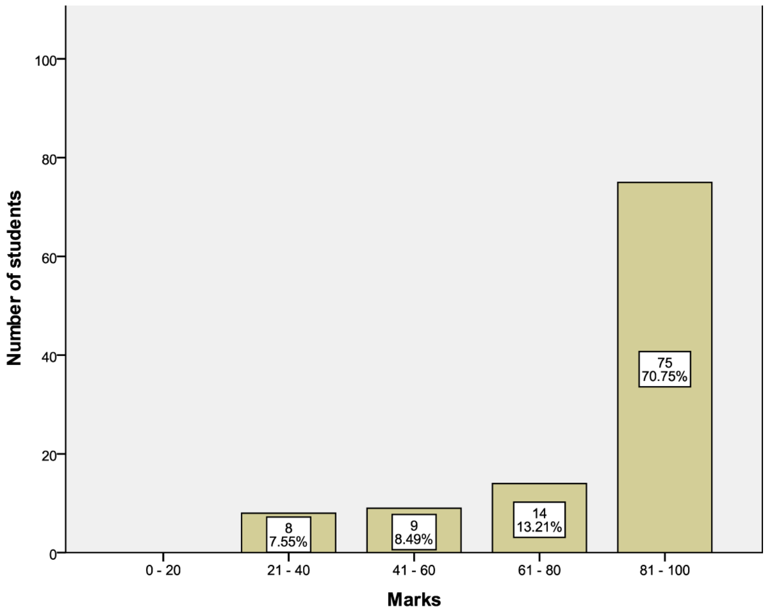

Figure 3: Quiz-1 marks.

and the online quizzes will compared using the Bloom's taxonomy (Bell, J. T., Scott, F., 1995).

3.2 Reliability

In order to analyse the reliability of the used questions in the online quizzes and the summative design assessment, a reliability coefficient of Cronbach's alpha (Gupta,S.C., and Kapoor,V.K., 2007) has been used. The reliability test results shows that Cronbach's alpha coefficient value of 0.665. (Hair, J.F., Black, W.C., Babin, B.J., and Anderson, R. E., 2009) states that the lower limit

Table 1: Reliability Statistics.

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Number of Items
.665	.667	3

for Cronbach's alpha of 0.60 is acceptable. Therefore, the reliability analysis shows an adequate consistency of the entire scale of the module assessments.

3.2 Content Validity

The summative design assessment has been designed to check the students understanding of the engineering design calculations and the application of the CAD software in engineering design. Similarly, the online quizzes have been designed to check the students understanding of the laboratory experiments. There are an adequate number of test questions in the summative design assessment and the online quizzes which include all the variables to be measured in order to determine if there is a correlation between the assessments. The assessment questions cover the complete syllabus of the module.

4. ANALYSIS OF THE DATA AND INTERPRETATION OF THE RESULTS

4.1 RQ1: Does the qualitative students' feedback provide an evidence that the module's teaching instructions are helping them in the experimental and the theoretical studies?

During the mid-term (in week 6^{th}) an online feedback questionnaire (appendix 1) has been given to the students. The feedback questionnaire is made available for the remaining six weeks of the term. Out of 106 students, 10 students have completed the feedback questionnaire. Feedback results show that 40% of the students have found screen casts on mechanical engineering topics useful and only 30% have not found the screencasts useful. Secondly, 88.89% of students have agreed that additional CAD software screencasts would be useful for completing the coursework. Thirdly, students have difficulty correlating the online screencast's theoretical knowledge to the coursework and preferred more face to face teaching related to the coursework. Fourthly, the students have suggested the requirement of the study support for the engineering design calculations and support for CAD software for non-mechanical engineering students. Fifthly, students suggested have organising face to face lectures and improving the teaching instructions on the engineering design coursework. They, find it difficult

Table 2: Marks obtained by students in quiz-1, quiz-2 and the design assessment.

	Marks (81%-100%)	Marks (61%-80%)
Quiz-1	70.75%	13.2%
Quiz-2	59.43%	30.19%
Design Assessment	25.47%	39.62%

to perform the design calculations and build the CAD assembly based on the design calculations. Therefore, from the above analysis, it has been concluded that the module's instructions are mostly focused on the experimental studies and that the experimental studies are not supporting the theoretical studies.

4.2 RQ2: Whether the experimental studies supports the theoretical studies?

The RQ has been answered in two stages. In the first stage, the quantitative data of the final marks obtained by the students in both the online quizzes and the summative design assessment, have been analysed for variation as follows,

4.2.1 RQ2.1: Is there a variation within the final marks obtained by the students in the theoretical study and the experimental study?

In order to answer this research question, the data has been analysed graphically using the bar graphs and the box plots.

The data are first graphically analysed using the bar graphs .The bar graph in figure 3 shows that in quiz-1 70.75% of the students have obtained the marks in the range of 81%-100%, followed by 13.2% of the students obtaining marks in the range of 61%-80% respectively.

The bar graph in figure 4 shows 59.43% of the students have obtained marks in the range of 81%-100%, followed by 30.19% of the students obtaining marks in the range of 61%-80% respectively.

The bar graph in figure 5 shows that the design assessment marks have a more uniform spread of marks with 25.47% of the students having obtained marks in the range of 81%-100%, followed by 39.62% of the students obtaining marks in the range of 61%-80%, respectively. The overall comparison of the students' academic performance is shown in table 2 below:

Table 2 shows that in the online quizzes, more number of students have obtained higher marks in the range of 81%-100%, compared to the design assessment. When the higher marks in the online quizzes are compared to the design assessment coursework, they provide evidence that there is a marks variation in the theoretical studies and the experimental studies.

Table 3: Spearman's rank-order Correlation Coefficient.

Spearman's Correlation Coefficient (r)		
	Quiz-2	Design assessment
Quiz-1	0.287[a]	0.397[a]
Design assessment	0.291[a]	

The boxplot graph in figure 6 shows median values of 100, 90 and 70.5 for the quiz-1, quiz-2 and the design assessment. It means that in quiz-1 50% of the students have obtained the marks at least 100%, in quiz-2 50% of the students have obtained the marks at least 90% and in the design report 50% of the students have obtained marks at least 70.5%. As the size of the quiz-1 and quiz-2 boxes is same, and quiz-1 has larger whisker than quiz-2 which means that quiz-1 has a greater amount of variation of the marks compared to quiz-2 and is shown by quiz-1 and quiz-2 SD values of 19.68 and 17.77. Box plots of both the quizzes have whiskers on lower side it, which means that the final marks were right skewed. The design assessment box size is larger than that of the both the quizzes, which indicates that there is a greater variation of the final marks that has been obtained by the students in the design assessment coursework. This is indicated by the SD values of 20.89 Second, the design assessment box has whiskers on both the sides, thus indicating that the final marks obtained by the students have been uniformly distributed. Hence, from the comparison results of the bar graphs and the box plots, it has been concluded that there is a marks variation between the online quizzes and the design report coursework.

In the second stage, the quantitative data of the final marks obtained by the students in both the online quizzes and the summative design assessment, have been analysed for correlation as the following illustrates,

4.2.2 RQ2.2: Is there a correlation between the final marks obtained by the students in the theoretical study and the experimental study?

In order to answer this research question, the data has been analysed statistically in two steps: Design assessment Vs Quiz 1 marks and Design assessment Vs Quiz 2 marks. In the first step, the first hypothesis between the quiz-1 marks and the design assessment marks is,

H_0: There is a no correlation between the quiz-1 marks and the design assessment marks.

H_1**:** There is a correlation between the quiz-1 marks and the design assessment marks.

Table 4: Comparison of the syllabus for the theoretical and the experimental studies.

Design assessment syllabus (Theoretical)	Experiments syllabus
CAD models	Stress, strain
CAD assembly	Hooke's law
Engineering design calculations	Wire resistance
Size description of shafts, gears, bearings	Strain gauge
Engineering drawings	Circuit to measure strain: quarter, half, full
Sectioned assembly	Cantilever beam experiment

a) $p < 0.05$

The scatter plot with a best fit line in figure 7 shows a slope, indicating a positive correlation between the quiz-1 marks and the design assessment marks.

In order to statistically determine the significance of the correlation, Spearman's rank-order correlation coefficient is calculated. The results show that there is a positive correlation between the quiz-1 marks and the design assessment marks obtained by the students, Spearman's rank-order correlation coefficient value is $r = 0.397$ ($-1 <= r <= 1$; -1 means strong negative correlation, 0 means no correlation and 1 means strong positive correlation, shown in Table 3) respectively ($\alpha = 0.05$) in the 106 cases. A scatter plot in figure 7 summarizes the results. Overall, there is a weak positive correlation between the quiz-1 marks and the design assessment marks obtained by the students. It means that the increases in the quiz-1 marks are correlated with the increase in the design assessment marks obtained by the students.

In the second step, the first hypothesis between the quiz-2 marks and the design assessment marks is,

H_0: There is a no correlation between the quiz-2 marks and the design assessment marks.

H_1**:** There is a correlation between the quiz-2 marks and the design assessment marks.

The scatter plot with a best fit line in figure 8 shows a slope, indicating a positive correlation between the quiz-2 marks and the design assessment marks.

In order to statistically determine the significance of the correlation, Spearman's rank-order correlation coefficient has been calculated. The results show that there is a positive correlation between the quiz-2 marks and the design

Table 5: Bloom's Taxonomy of Cognitive Objectives (Bell, J. T., Scott, F., 1995).

Level 1	Knowledge	Fact recall with no real understanding behind the meaning of the fact.
Level 2	Comprehension	The ability to grasp the meaning of the material.
Level 3	Application	The ability to use learned material in new and concrete situation.
Level 4	Analysis	The ability to break complex problems into parts.
Level 5	Synthesis	The ability to put parts to gather to create a unique new entity.
Level 6	Evaluation	The ability to judge the value of the material for given purpose.

Table 6: Comparison of the evaluation criteria of the summative design assessment and the online quizzes according to Bloom's Taxonomy.

Quiz 1	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**
Determine (8 questions)	Yes	Yes				
Estimate (2 questions)	Yes	Yes				
Quiz 2						
Determine (9 questions)	Yes	Yes				
Definition (1 questions)	Yes	Yes				
Design assessment						
CAD Models	Yes	Yes				
CAD Assembly	Yes	Yes				
Engineering design calculations	Yes	Yes	Yes	Yes	Yes	
Engineering drawings	Yes	Yes				
Sectioned assembly	Yes	Yes				

assessment marks obtained by the students, Spearman's rank-order correlation coefficient value was r =0.291 (Table 3) respectively ($\alpha = 0.05$) in the 106 cases. A scatter plot in figure 8 summarizes the results. Overall, there is a weak positive

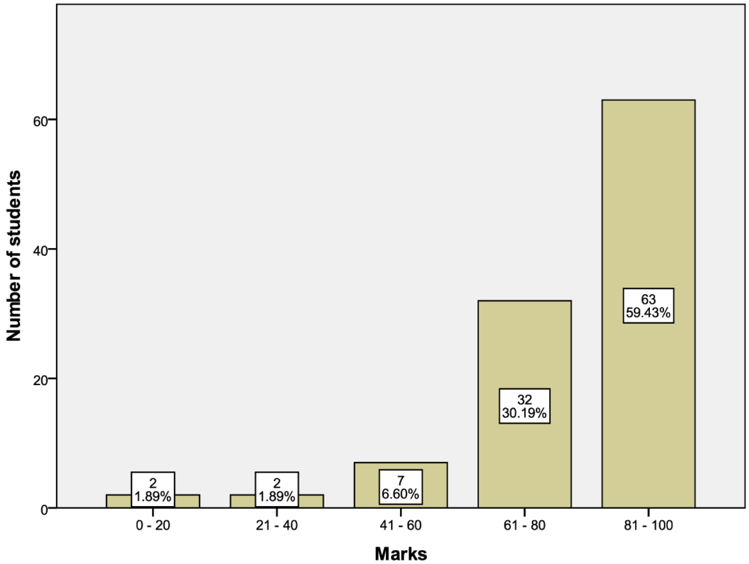

Figure 4: Quiz-2 marks**.**

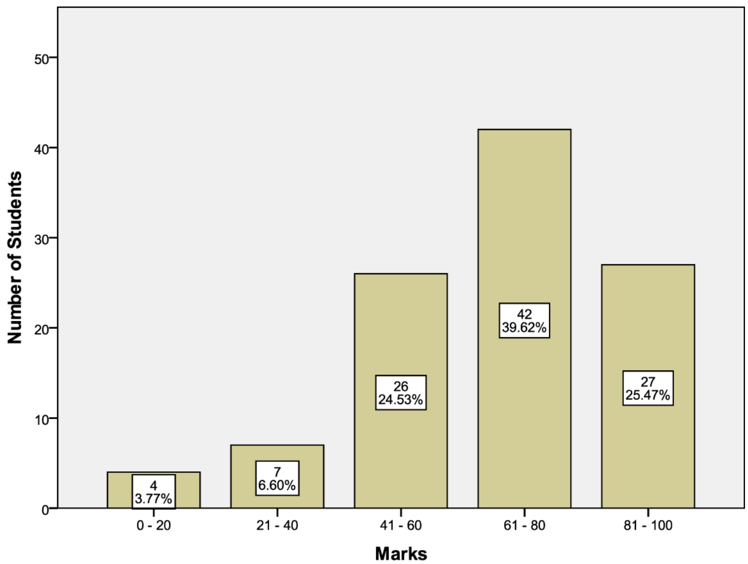

Figure 5: Design assessment marks.

correlation between the quiz-2 marks and the design assessment marks obtained by the students. It means that the increases in the quiz-2 marks are correlated with the increase in the design assessment marks obtained by the students.

Table 3 summarises Spearman's rank order correlation coefficients for the online quizzes and the design assessment coursework. It has been found that marks in both the quizzes have weak positive correlation with the design assessment marks.

Therefore, the variation and weak positive correlation between the marks obtained by the students in the theoretical studies and the experimental studies indicates that the theoretical studies and the experimental studies do not completely complement each other. As a result, the syllabi of the theoretical and the experimental studies are compared, as shown in the table 4 below:

The table 4 above shows that the theoretical engineering design calculations are indirectly related to the topics being taught in the laboratory experiments. Therefore, it has been concluded that the theoretical studies and the experimental studies indirectly support each other.

4.3 RQ3: Whether the students are given opportunities to develop engineering application skills?

In order to answer this RQ, the evaluation criteria of the summative design assessment and the online quizzes is compared using the Bloom Taxonomy (Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R., 1956). Bloom's taxonomy states that in order to achieve the deeper understanding of the subject matter, teachers should strive to guide their students to the higher levels of the taxonomy as shown in table 5 below:

The table 6 above shows that the summative design assessment is evaluating the students' skills up to five levels, whereas the experimental knowledge is being evaluated up to two levels of the Bloom's taxonomy. In addition, the students assessment scheme is focused on assessing students' academic performance on the basis of the task's completed in both design and experimental work rather according to their abilities to perform at different levels of the Bloom's taxonomy.

Therefore, as the syllabus of the theoretical studies and the experimental studies are indirectly related to each other (table 4) and the students are being evaluated at different levels according to the Bloom's Taxonomy (table 6), has been concluded that students are not provided with adequate opportunities to develop the engineering application skills.

5. DISCUSSION AND IMPLICATIONS FOR THE PRACTICE

First, the RQ1 result shows that the screencasts on ME topics and on the CAD software help students with the engineering design assessment. Backed by this finding, it can be said that in addition to the face to face instructions,

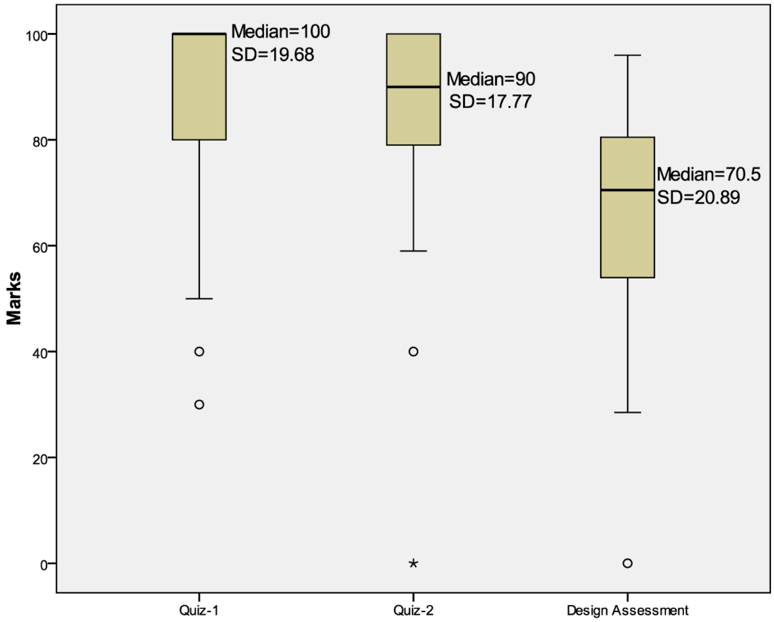

Figure 6: Boxplots for Quiz-1, Quiz-2 and Design Assessment.

screencasts based instructions are also useful in teaching the module. Therefore, visual learning (Felder & Brent, 2004) instructions comprising of pictures, screenshots along with interactive questions may be designed to improve the students' conceptual understanding and encourage them, to actively participate in the learning. The students' suggestion on organising face to face lectures for the engineering design coursework emphasises the need to provide teaching instructions on the engineering design assessment and on the laboratory experiments, in order to improve the students learning experience on the module.

Second, the RQ2 results shows that the theoretical studies and the experimental studies are indirectly supporting each other as there is a significant difference in the students' academic performance in both the studies. For instance, in quiz-1 and quiz-2, 70.75% and 59.43% of students' obtained marks in the range of 81%-100% compared to 25.47% of students' who obtained marks in the same range in the design assessment. In addition, there is a weak positive correlation between the marks obtained by the students in the quizzes and the design assessment ($r_{quiz1\_Design\ assessment}$=0.397; $r_{quiz2\_Design\ assessment}$=0.291) indicates that both studies are partially complementing each other. However, table 4 provides an evidence that both the studies are indirectly related to each other.

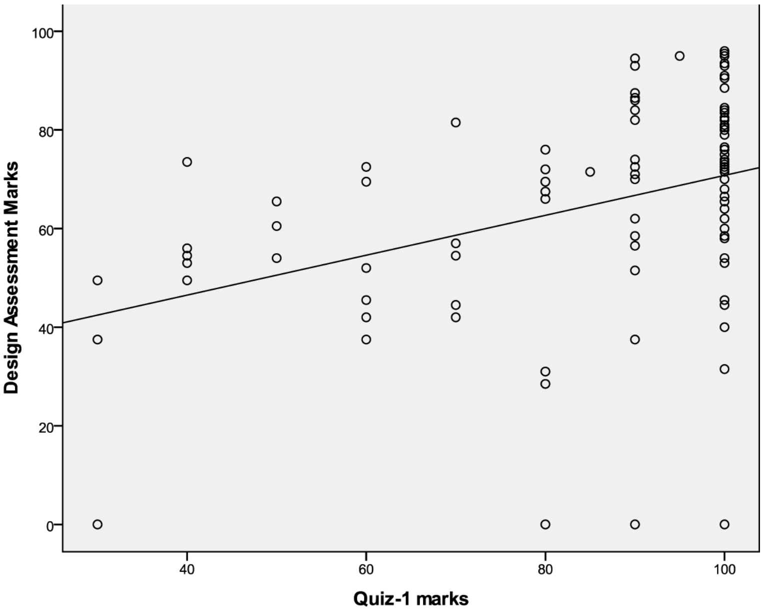

Figure 7: Scatter plot between Quiz-1 marks and Design assessment Marks.

These findings are supported by the students' online feedback where they have suggested additional lectures for the theoretical calculations and are having difficulty correlating the screencasts theoretical knowledge to the engineering design coursework. This indicates that students visualise both the studies as two independent components of the module. Therefore, in order to effectively teach engineering application skills to the students, the laboratory experiments may include the experience related to the engineering design calculations. For instance, instead of using a cantilever beam, the laboratory experiments may use the gear box shaft to find the stress and strain, using the strain gauges and they may also include experiments such as assembly of the gear box, which will help students in correlating the engineering design calculations with the actual assembly components. It will also provide students hands on experience (Manolis et al., 2013) on assembling the actual gear box and help them clearly visualise the interplay between the assembled components directly related to the design assessment. The lecturers should also provide them instructions to help students to correlate the laboratory experiments with the engineering design calculations.

Third, the RQ3 results shows that students are not provided an adequate opportunities to develop the engineering application skills. For instance, table

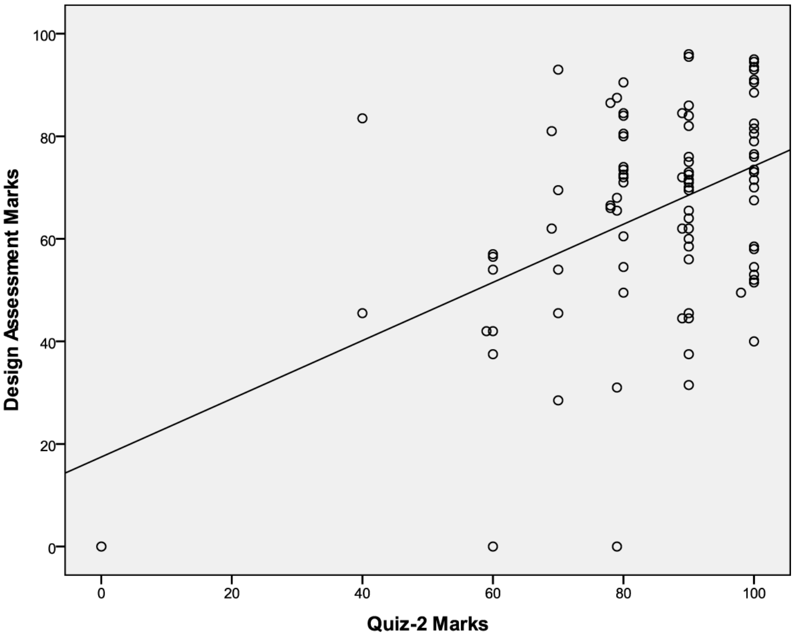

Figure 8: Scatter plot between Quiz-2 marks and Design assessment Marks.

4 showing an indirect relation between the theoretical and the experimental syllabus emphasised a need for lecturer's to have good facilitation skills while adopting a constructivist approach and to provided students' with an adequate deep learning opportunities in the PBL environment (Donnelly, 2005). Whereas, table 6 shows that according to Bloom's Taxonomy, the laboratory experiments are being evaluated for the first two level i.e. knowledge recall and the comprehension, and the engineering design assessment is being evaluated for up to five levels such as knowledge recall, comprehension, application, analysis and synthesis. As a result, students are adopting deep learning (Erhan et al., 2010) approach in the engineering design assessment and the surface learning (Richardson, 2011) approach in the laboratory experiments. On the other hand, students also have expectations that laboratory experiments will help them in understanding the engineering design calculations. Backed by this finding, it can be said that in order to provide students with an opportunities to develop engineering application skills, the laboratory experiments should be based on the engineering design topics which will help them in performing the engineering calculations. In addition, the learning activities and the students' assessment scheme in both the experimental and the theoretical studies may be based on the six levels of the Bloom's Taxonomy in order to encourage

students to adopt deeper learning approach in the PBL environment of the module.

It implies that lecturer's should constructively align (Biggs, J., Tang,C., 2007) the engineering modules, in order to enhance the students' learning experience in the PBL environment. The teaching team may use concept mapping (Noble et al., 2011) tools such as compendium (Open University, 2013) to make use of graphical mapping technique to visually determine the curriculum competencies covered and areas not sufficiently covered and to evaluate the effectiveness of the teaching practices on the students learning experience (Plaza et al., 2007). The learning activities design should also take into consideration the learning styles of the engineering students to encourage them to actively participate in the PBL environment (Domin, 1999). In addition, the educational institutions should also provide support to the academics to improve their facilitation skills in the challenging PBL environment (Mantri, Dutt, Gupta, & Chitkara, 2008).

6. CONCLUSIONS

The aim of this study has been to investigate the effectiveness of the theoretical and laboratory teaching on the students' academic performance, and to improve the students learning experience in the module. In particular, the current study has two objectives: (1) To evaluate the students' learning experience in the theoretical and experimental studies, (2) To provide suggestions on the teaching and learning activities, in order to improve the students learning experience in the module. The study has found that the module's instructions are mostly focused on the experimental studies and has established that experimental study is not supporting the theoretical study. Second, it has discovered that the theoretical studies and the experimental studies are indirectly supporting each other. Third, it has evinced that the students are not provided with an adequate opportunities to develop the engineering application skills.

The main findings therefore are, first that the visual learning instructions comprising of pictures, screenshots along with interactive questions may be designed to improve the students' conceptual understanding and encourage them, to actively participate in the learning. In lectures, the teaching instructions should focus on both the engineering design assessment and on the laboratory experiments, in order to improve the students learning experience in the module. Second, in order to effectively teach engineering application skills to the students, the laboratory experiments may include the experience related to the engineering design calculations. For instance, the laboratory experiments may use the gear box shaft to find the stress and strain using the strain gauges and may also include experiments such as an assembly of the gear box which will help students correlate the engineering calculations with the actual assembly components. This will also provide students' with hands on experience on assembling the actual gear box and to clearly visualise the interplay between the assembled components directly related to their design calculations. The lecturers should also provide teaching instructions to help students' correlate the engineering calculations with the laboratory experiments. Third, in order to provide students with opportunities to develop engineering application skills, the laboratory experiments should be based on the design calculations topics to help them in performing the engineering design calculations. In addition, the learning activities in both the theoretical and the experimental studies may be based on the six levels of Bloom's Taxonomy in order to encourage students to adopt deeper learning approach in the PBL environment of the module.

The results imply that lecturer's should constructively align the engineering modules to improve the students learning experience in the PBL environment. The concept mapping tools like Compendium, may be used to visually determine the curriculum competencies covered and areas not sufficiently covered, to evaluate the effectiveness of the teaching practices on the students learning experience. The learning activities design should also take into consideration the learning styles of the engineering students in order to encourage them to actively participate in the PBL environment. In addition, the educational institutions should also provide support to the academics to improve their facilitation skills in the challenging PBL environment.

A suggested direction for further research is to evaluate the effectiveness of the theoretical and experimental instructions based on the six levels of the Bloom's Taxonomy on the students learning experience.

REFERENCES

[1] Bell, J. T., Scott, F. (1995). The Investigation and Application of Virtual Reality as a Educational Tool. In Proceedings of the American Society for Engineering Education 1995 Annual Conference.

[2] Biggs, J., Tang,C. (2007). Teaching for Quality Learning at University. Open University Press.

[3] Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). Taxonomy of educational objectives (1st ed.). New York: McKay Co D.

[4] Domin, D. S. (1999). A Review of Laboratory Instruction Styles. Journal of Chemical Education, 76(4), 543. http://dx.doi.org/10.1021/ed076p543

[5] Donnelly, R. (2005). Using Technology to Support Project and Problem-based Learning, 157–177.

[6] Dumitrescu, C., Olteanu, R. L., Gorghiu, L. M., Gorghiu, G., & State, G. (2009). Using virtual experiments in the teaching process. Procedia - Social and Behavioral Sciences, 1(1), 776–779. http://dx.doi.org/10.1016/j.sbspro.2009.01.138

[7] Erhan, D., Courville, A., & Vincent, P. (2010). Why Does Unsupervised Pre-training Help Deep Learning ? Journal of Machine Learning Research, 11, 625–660. Retrieved from http://portal.acm.org/citation.cfm?id=1756025

[8] Felder, R. M., & Brent, R. (2004). the Abc ‘ S of Engineering Education : Abet , Bloom ‘ S Taxonomy , Cooperative Learning , and So on. Engineering, 1. Retrieved from http://156.35.81.1/docs/IJPEI/ABET_Criteria_PTE/ABET_Bloom's_taxonomyASEE04.pdf

[9] Felder, R.M., Silverman, L. K. (1988). Learning and Teaching Styles. Engineering Education, 78(7), 674–681.

[10] Fink, D.,Ambrose,S.,Wheeler, D. (2005). Professional EngineeringEducator.pdf. Journal of Engineering Education, 1(1), 185–194.http://dx.doi.org/10.1002/j.2168-9830.2005.tb00837.x

[11] Güneş, T., Dilek, N. Ş., Çelikoğlu, M., & Demir, E. S. (2011). The using levels of the teaching methods and techniques by teachers. Procedia - Social and Behavioral Sciences, 15, 1092–1096. http://dx.doi.org/10.1016/j.sbspro.2011.03.244

[12] Gupta,S.C.,Kapoor,V.K. (2007). Fundamentals of Applied Statistics. Sultan Chand & Sons.

[13] Hair, J.F., Black, W.C., Babin, B.J., and Anderson, R. E., Hair, J.F., Black, W.C., Babin, B.J., and Anderson, R. E. (2009). Multivariate Data Analysis - A Global Perspective. New Jersey: Pearson Education Inc.

[14] Houghton, Dr. W. (2004). Learning and Teaching Theory Engineering Subject Centre Guide : Learning and Teaching Theory for Engineering Academics.

[15] Kverenbekk, T. (2012). Argumentation in Theory and Practice : Gap or Equilibrium ?, 32(3), 288–305.

[16] Manolis, C., Burns, D. J., Assudani, R., & Chinta, R. (2013). Assessing experiential learning styles: A methodological reconstruction and validation of the Kolb Learning Style Inventory. Learning and Individual Differences, 23, 44–52. http://dx.doi.org/10.1016/j.lindif.2012.10.009

[17] Mantri, a., Dutt, S., Gupta, J. P., & Chitkara, M. (2008). Design and Evaluation of a PBL-Based Course in Analog Electronics. IEEE Transactions on Education, 51(4), 432–438. http://dx.doi.org/10.1109/TE.2007.912525

[18] Ming-chao, L., & Jing, L. (2012). Goal-Oriented Method and Practice in Experimental Teaching. IERI Procedia, 2, 480–484. http://dx.doi.org/10.1016/j.ieri.2012.06.120

[19] Noble, C., O'Brien, M., Coombes, I., Shaw, P. N., & Nissen, L. (2011). Concept mapping to evaluate an undergraduate pharmacy curriculum. American Journal of Pharmaceutical Education, 75(3), 55. http://dx.doi.org/10.5688/ajpe75355

[20] Plaza, C. M., Draugalis, J. R., Slack, M. K., Skrepnek, G. H., & Sauer, K. A. (2007). Curriculum mapping in program assessment and evaluation. American Journal of Pharmaceutical Education, 71(2), 20. http://dx.doi.org/10.5688/aj710220

[21] Richardson, J. T. E. (2011). Approaches to studying, conceptions of learning and learning styles in higher education. Learning and Individual Differences, 21(3), 288–293. http://dx.doi.org/10.1016/j.lindif.2010.11.015

[22] Standal, O. F., Moen, K. M., & Moe, V. F. (2013). Theory and practice in the context of practicum: The perspectives of Norwegian physical education student teachers. European Physical Education Review, 20(2), 165–178. http://dx.doi.org/10.1177/1356336X13508687

[23] University, O. (2013). Compendium Institute. Retrieved January 1, 2015, from http://compendium.open.ac.uk/institute/download/download.htm