Case study of failure analysis of engineering components: Effects on employable skills, conceptual understanding, and perception.

E. O. Olakanmi[1*]
Senior Lecturer
Department of Mechanical, Energy & Industrial Engineering,
Botswana International University of Science & Technology,
Palapye. Botswana.
olakanmie@biust.ac.bw

Joe B. Agboola
Senior Lecturer
Department of Mechanical Engineering
Federal University of Technology
Minna, Niger State, Nigeria.
joe_agboola@yahoo.com

Eunice Eyitayo Olakanmi
Post-Doctoral Research Fellow
Department of Science & Technology Education,
University of South Africa,
Pretoria, South Africa
e.e.olakanmi@gmail.com

B. Nthubu
Teaching Instructor
Department of Mechanical, Energy & Industrial Engineering,
Botswana International University of Science & Technology,
Palapye. Botswana.
nthubub@biust.ac.bw

Abstract:
The need exists for a new approach of engineering training which incorporates the development and the assessment of work-based skills that cannot be imparted and examined with traditional instructional delivery and written examinations respectively. To address this need, this study explores a twenty-week case study to teach employable skills and concept of failure analysis to final year mechanical engineering students in a Nigerian University. The case study worked upon by each group and a plurality of solutions with a view to helping students develop a range of professional, transferable and team working skills under the guidance of the first two authors. We carried out continuous assessment of the competences gained by our students via fortnightly review meetings, oral presentation, working models, written project reports and interviews.

Corresponding Author: E. O. Olakanmi
e-mail address: olakanmie@biust.ac.bw

Students' conceptual understanding was enhanced while they also developed skills in independent critical thinking, formulation, analysis, optimisation and evaluation of the performance of their designs and communication of their ideas effectively. Finally, this study highlights our rationale for adopting the case study and the good practice we have identified, and also discusses our experiences of the adoption and implementation of this type of learning activity.

Keywords: Case study; Nigerian University System (NUS); Materials design and selection; Employable skills.

1 INTRODUCTION

There is a need to ensure engineering students develop skills that cannot be assessed in traditional written examinations yet are essential for work as engineer; and at the same time bring realism into the study of engineering by integrating previous experience of theory and practice. This necessitates that a new approach of training should be incorporated into the traditional lecture-based engineering curriculum [1-3]. Such a training programme should equip engineering graduates with excellent planning, communication skills, team working ability and sound analytical and evaluation skills in line with employers' expectations [4, 5]. The case study, an innovative educational teaching and learning methodology grounded in social cognitive theory [6, 7], inspires a higher degree of students' involvement in learning activity [3, 8, 9]. In social cognitive theory, students are expected to engage in socially mediated group problem-solving processes. The case study is implemented with students learning through engagement with engineering projects similar to that which will be encountered in professional practice [3, 10, 11]. The incorporation of the case study into the materials selection and design curriculum is aimed at meeting the need for a new approach of engineering training which ensures the development and assessment of work-based skills that cannot be imparted and examined via traditional instructional delivery and written examinations respectively.

Despite the popularity of the case study approach within engineering, its use in the Nigerian materials design and selection curriculum has not become widespread as most educators have limited knowledge of how to incorporate it into their classrooms. In addition, empirical studies on the effectiveness of the case study are limited and the research that does exist had primarily focused on students' perceptions of their learning rather than how it imparts conceptual understanding and employable skills into students offering materials design and selection curriculum. In this preliminary study, we investigated how the incorporation of the case study alongside the traditional teaching method could impart employable skills and conceptual understanding into students offering materials selection and design curriculum. To achieve this aim, we carried out continuous assessment of the competences gained by our students via students' involvement in weekly review meetings, oral presentation, working models, written project reports, and interviews while they explored solutions utilising various engineering concepts that would be used by an engineer in practice while still relating them to documented theory. This research answers the following research questions:

- What employable skills and conceptual understanding are imparted to students offering materials selection and design curriculum when the case study is adopted to teach failure analysis?
- What are the students' perceptions on the adoption of the case study teaching instruction in a materials design and selection curriculum?
- How the case study does impart employable skills and conceptual understanding to students offering materials selection and design curriculum?

2 METHODOLOGY

2.1 Implementation of the case study

The case study took place over 20-week with students spending a period of 5 to 7 hours per week including 3 hours of weekly lecture and another 2 to 4 hours meeting by each group. During the first lecture, the authors presented the course outline and outcomes to final year mechanical engineering class comprising of 80 students in 2009/2010 academic session. Students were informed that the curriculum would have a case study component in addition to the traditional lecture method. Students were distributed into groups comprising of eight members. Each group was asked to look for a failed engineering component. Then, each group was instructed to investigate what caused the failure of the component, develop possible re-design solutions to prevent untimely failure of the components, and thereafter implement the most technologically feasible solution in regards to manufacturing.

Typical damaged engineering components investigated by the groups included pruning shears, sign boards, door keys, car door handle e.t.c. The choice of these components was premised on the need to organise the case study around course content and available facilities. Moreover, students were encouraged to take responsibility for defining their learning experience and planning project activities and collaborate via learning teams. Prior to implementing the case study, each group was requested to prepare planning schedule. The first two authors assessed the planning schedules and offered suggestions on how planning schedules could be improved upon. Students were informed that it is required that they demonstrate the results of their learning through a product and/or performance at the time of oral presentation and submission of written report twelve weeks after the first lecture. They were also informed that the assessment criteria would comprise of the oral presentation/working model (Table 1) and the group written reports (Table 2) developed in accordance with Gibson [8].

For oral presentation/working model assessment scheme, the main emphasis was on comprehension of the researched material (Table 1while the written report (Table 2) emphasised on methodology, understanding and content of the case study. We concur with Gibson [8] that our students should be rewarded for taking on and completing technically difficult projects, hence, these assessment criteria were adopted for examining all the prime learning targets which students were expected to have met upon their exposure to the case study.

Table 1. Oral presentation assessment scheme used in this study

	Poor	Fair	Good	Very Good	Excellent
Presentation skills					
Introduction	0.5	1	1.5	2	2.5
Structure	0.5	1	1.5	2	2.5
Content					
Relevance of material	1	2	3	4	5
Depth of research	1	2	3	4	5
Comprehension					
Grasp of content	2	4	6	8	10
Response to questions	2	4	6	8	10
Working model	1	2	3	4	5

Meanwhile, each team appointed one leader and met weekly throughout the first semester of 2009/2010 session to specify their various time-lines and discuss approaches of implementing their case study with the leader allocating different tasks to each team member. With the support of the first two authors, the team leaders ensured team interactions and unhindered communications with a view to achieving timely and successful implementation of their the case study. Each team also met the first two authors fortnightly for briefing on the progress already made as well as challenges being encountered. During the briefings, we recorded in a notebook our observations of the nature of involvement of the team members for analysis. Each group was commended by the authors when significant progress was made while suggestions were offered to the groups in overcoming their challenges. Two weeks after the submission of the written reports, oral presentation took place during which members presented their case study and clarified their involvement, conceptual understanding and employable skills acquired. Typical clarifying questions asked included the following:

- Why is failure analysis important to your training as an engineer? (Conceptual understanding, formulation)
- How would you describe failure analysis?
- How did you carry out failure analysis? (Analysis)
- On the basis of your experience from the case study, identify the factors responsible for the occurrence of component failure. Clarify how these factors influence component failure? (Conceptual understanding, analysis, evaluation)
- What suggestions did your group propose in preventing untimely failure of components? Which of the suggestion(s) did your group implement and why? (Conceptual understanding, analysis, evaluation, optimisation)
- Using your experience from the case study, how did you incorporate re-design into manufacturing? (Conceptual understanding, formulation)
- Describe how your group re-manufactured the working model? (Conceptual understanding, formulation)

These questions were validated by a senior Professor of materials science and engineering whose comments were used to alter and improve the questions before they were administered to students. Five students were interviewed with a view to gaining insight into students' perception of the incorporation of the case study into materials selection and design curriculum.

Table 2. Written report assessment scheme used in this study

	Poor	Fair	Good	Very Good	Excellent
Presentation skills					
Layout, references, language e.t.c.	1	2	3	4	5
Methodology and Understanding					
Comprehension, analysis	2	4	6	8	10
Synthesis, organisation of ideas	2	4	6	8	10
Evaluation, objectivity	2	4	6	8	10
Content					
Information evaluation, fieldwork	1	2	3	4	5
Laboratory/manufacturing work, modelling, creativity	1	2	3	4	5
Mathematical skills and software design	1	2	3	4	5

Typical questions asked were as follows:

- What do you like about the case study you have carried out on failure analysis of engineering components?
- How do you plan to use what you have learnt during the case study in your professional practice?
- What do you perceive to be the role of the tutors in the case study?
- Which of case study or traditional lecture method do you prefer? Give reasons.
- What do you dislike about the case study?
- How do you think your experience of case study could be improved upon?

2.2 Data Analysis

This study employed qualitative analysis of data mainly oral presentation, interviews and observation notes. Students' responses and group's written reports were assessed based on the assessment criteria employed by Gibson [8] (Tables 1 and 2). For instance, a score of 2 was awarded if the student was unable to demonstrate a grasp of content of the failure analysis of a component, 4 was assigned if the student showed some grasp of failure analysis, but was unable to apply the concept of failure analysis to a given real life problem (i.e., fair understanding), 6 was assigned if the student exhibited good grasp of failure analysis, but was unable to apply the concept of failure analysis to a given real life problem in a clear and succinct manner (i.e., good understanding), and a score of 8 – 10 was assigned if the student accurately apply the concept of failure analysis to a given real life problem in a clear and succinct manner with no false starts (i.e., very good/excellent understanding) (Table 1).

Students' responses were divided into categories of conceptual understanding and employable skills (e.g. conceptual understanding, formulation, analysis, evaluation, and optimisation e.t.c.) for analysis (see Table 3 adapted from Gibson [8]). Furthermore, observation notes were analysed by describing students' interactions during fortnight briefings, oral presentation and interview, details of the participants' involvement and the events witnessed. This assisted in identifying the relevant emerging themes. Meanwhile, analysis of observation notes also included our reflections on the relationships formed between the participants in the same group, thoughts on what the participants said and how it was said, and reactions. Therefore, the existence, meanings, and relationships of the words or concepts that were related to the development of conceptual understanding and employable skills were explored and noted down during the process of analysis.

Table 3. Coding scheme adapted from Gibson [8] for this study

Evaluation	Ability to make a judgement of the worth of something
Analysis	Ability to break a problem into its constituent parts and establish a relationship between each one Apply an understanding of the importance of human and environmental factors in design and manufacturing
Formulation	Ability to apply rephrased knowledge to novel situations Ability to define problems and develop design specifications
Conceptual understanding	Ability to recall and rephrase knowledge Ability to apply the fundamentals of engineering science and mathematics to real life engineering problem
Optimisation	Have the ability to generate and develop alternative solutions to design problems and then make informed and/or most desirable choices as to the preferred solution Ability to combine separate elements into a whole
Communication	Ability to employ transferable skills such as oral and visual skills, team working, the ability to “learn how to learn”, and the ability to synthesise and apply acquired knowledge to the solution of problems A good understanding of, and familiarity with, modern Information and Communication Technologies (ICT) to express ideas
Critical thinking	Ability to generate and develop alternative solutions to design problems and then make informed and/or most desirable choices as to the preferred solution
Time management	Ability to complete a given assignment according to schedules
Conflict management	Ability to mediate and bring cohesive relationship.

The interview data from the students used were also analysed by categorisation. To ensure objectivity in the coding process, validity and reliability aspects were also considered. Two coders (the third author and another expert in education research methods) participated in the categorisation process. The coders separately searched for items in various data which demonstrated each item of the coding scheme in Table 3 and then compared and discussed their selections. After coding, the inter-rater reliability was calculated (Holisti’s coefficient) for both coders. After the computation of the inter-rater reliability, the coders discussed any controversial cases until they reached 100% agreement.

3 RESULTS

3.1 Nature of imparted employable skills and conceptual understanding

The use of case-study enabled our students to develop hands-on-skills and transform from “passive learners” to “team members.” For instance, student P’s (from group VIII) response “*--- because I was actively involved in the planning and analysis of the damaged cutlass, its re-designing, and fabrication. ---- Better than the lecture methods in which the lecturers just talk all through---------. Ummm! ----- I could think through and understand failure analysis better than using lecture notes alone----------” me.*” to the question “*which of the case study or the traditional lecture method do you prefer in teaching materials selection and design curriculum*?” supported the claim that the use of case-study transformed “passive learners” to “team members” who engage in active learning.

The development of hands-on- skills is evident in the re-manufacturing of pruning shear with heavy metal handle by group I (Figure 1). According to student A (group I), pruning shear was re-manufactured using the following procedure:

- Metal handles were cut off from the pruning shear by using hack-saw
- Wooden handles from a damaged pruning shear were carefully removed using hand tools (Figure 1)
- The pruning shear blades were then sharpened using grinding machines
- The pruning shear blades were fastened to the wooden handles using a thin metal sheet in order to reduce weight of the pruning shear for effecting cutting operation.

Fig.1. The pruning shear manufactured group I after testing.

Students' response to the question "*why is failure analysis important to your training as an engineer?*" established they developed skills in formulating an engineering problem. Student G's response from group IV that "*investigating component failure is important because experience need to be gained from studying which factors (either wrong material selection, poor design criteria, or poor manufacturing practice) resulted in a damaged part so that re-occurrence could be avoided in future in order to save financial resources to be used for re-manufacturing*" affirmed this assertion. Another student H from the same group also mentioned of "*the need to save lives as inappropriate design and poor material selection could cause destruction of lives and properties as evident through the recurring incident of collapsed buildings in various parts of Nigeria as at 2010*."

Moreover, each group developed scheduled plan of activities detailing how they would progress with various activities assigned to each member within a specific period of time. Table 4 shows the scheduled plan of activities developed by group I detailing how they would progress with the case study on the failure analysis of pruning shear. Hence, students learnt the art of effective time management as we noted each group worked within the planned schedule.

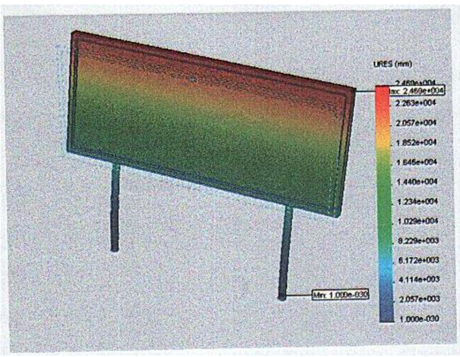
The development of conceptual understanding, independent critical thinking and optimisation skills by the participants were quite evident in responses of student M from group VII who re-designed a wind damaged signboard to the following questions during the oral presentation:

- What suggestions did your group consider in re-designing the damaged signboard
- Describe the suggestion(s) your group implemented
- Explain why you have implemented your chosen suggestion?

Table 4. Schedule of activities for group Ion the case study for failure analysis of pruning shear.

	Week 1-2	Week 3-6	Week 7-10	Week 11-14	Week 15-18	Week 19-20
Activity	Visitation to the accident site for to gather pre-liminary data on failed pruning shear	Analysing pre-liminary data to find out causes of failure of pruning shear	Re-designing of failed part. Planning for re-manufacturing of pruning shear	Re-manufacturing of failed pruning shear and testing.	Writing of reports; Submission of written reports and working models of pruning shear	Oral presentation

In proposing solution options to re-design the damaged signboard, student M claimed that his group members employed mathematical/analytical techniques in re-designing the signboard. According to student M, "*we reasoned that if the previous manufacturers had determined the environmental wind resistance in Minna, as well as the appropriate geometrical and material parameters to withstand the wind resistance and the atmospheric corrosion, incessant damage of the signboards wouldn't have been occurring in the University. Therefore, we thought it wise to use modelling techniques (Figure 2) to determine geometrical and materials parameters to withstand the wind resistance in Minna environment*."

(a) 

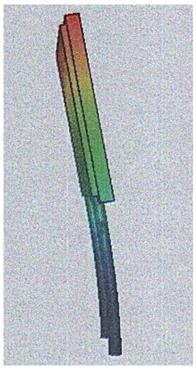
(b) 

Figure 2. Displacement diagram of the billboard when wind stress was applied (a) front view (b) side view

He also pointed out that mathematical equations were used to estimate the wind resistance exerted on erected structures by using wind parameters associated with Minna town. The group also considered what effect the wind resistance may have on various geometries of the signboard. Some of the geometries considered included rectangles of various dimensions (thicknesses, length, breadth) and triangular shapes. Geometrical parameters were inserted into equations for the optimisation of the wind resistance of the signboard. Thereafter, a rectangular signboard with optimised dimensions was chosen as the appropriate one to withstand the wind resistance in Minna town.

Student M went further to explain that tables of comparative analysis of various materials were drawn up on the basis of mechanical properties, cost, availability, and atmospheric corrosion resistance with a view to making an appropriate choice of material to produce the signboard. It is pertinent to note that students' ability to realise that previous manufacturers did not give consideration to the appropriate material and geometric constraints to enable the signboards withstand the wind resistance in Minna illustrate the development of conceptual understanding of materials selection and design as well as independent critical ability. Moreover, the use of comparative tables on basis of various factors affecting the durability of the signboard shows that students had been able to demonstrate ability to carry out evaluation in order to optimise the functionality of the signboard.

Analysis of students' description of important concepts such as failure analysis, re-design of engineering components, mechanical properties, and corrosion, during the oral presentation reveals that they had correct understanding of these engineering concepts as it related to their group case studies both at individual and group levels. Since the aim of engaging students in case study is to help them improve in their conceptual understanding at individual level, it is evident that participation by student F (a member of group III) helped him to describe failure analysis as "*the collection of data to determine the cause of failure of an engineering part. It is useful in developing new products and to improve the functionality of manufactured parts.*" The student attributed his ability to define this concept correctly to his practical engagement in going (alongside his colleagues) to the site where the failure of the part occurred to ask questions on what happened prior to, during, and after the occurrence of failure; and brainstorming together with his colleagues to ascertain the factors responsible for the failure as well as proffering and implementing appropriate solutions for re-designing and manufacturing of failed component.

In summary, evaluation of students' observations and responses section during the fortnight briefings and the oral presentation respectively confirm that individual students actually gained proficiency in the grasp of examined engineering concepts. Moreover, an examination of the groups' written reports revealed that relevant concepts were correctly defined, while the layout, comprehension, analysis, evaluation, and mathematical techniques presented in each of the reports were adjudged to be very good.

Table 5 shows that students' academic performance was better during 2009/2010 academic session when both case study and traditional lecture method were used as instructional delivery technique in comparison to 2008/2009 session when only traditional lecture method was used to deliver materials design and selection module. Finally, it may be concluded that students had a grasp of the methodology, understanding, and content of the concept of failure analysis of engineering components going by observations made during the fortnight briefings, assessment of oral presentation and written reports.

Table 5. Students' performance in materials design and selection module over two sessions.

Grades	Excellent	Very good	Good	Fair	Poor
2009/2010	2%	17%	32%	34%	15%
2008/2009	-	10%	25%	32%	33%

3.2 Students' perception of the adoption of case-studies for teaching failure analysis

Table 6 obtained via students' interview reveals that students held positive perceptions about the adoption of case-studies for teaching failure analysis as they claimed that it enabled them to think critically about failure analysis of engineering components and relate the lecture notes to the reality. A student was also of the view that the public speaking skills acquired from her participation in case study will help her to function well in a sales environment while another student was of the opinion that his working in a team with members of diverse interests and abilities will help him to function well in a multi-cultural working environment in the future. Students believed that the use of case study in teaching failure analysis helped them to take control of the learning process while the tutors only facilitate the learning process. Students expressed preference for case study over the traditional lecture delivery method because it helped them to think through and understand failure analysis much better than they would have done with the use of traditional lecture method alone. Nevertheless, some students complained about the rigorous nature of undertaking case studies, longer hours of group meetings as well as group members who were not committed to the group goal.

4. Discussion of Results

In agreement with Gijselaers [12]; Graaff and Kolmos [13] and Majeed [14], learning about engineering concepts such as failure of engineering components entail rigorous analysis through case study because it takes a lot of time to master the learning process (Table 6), coupled with its inter-disciplinary nature which demands that students employ their prior knowledge gained across the fields of manufacturing/production, material selection, design, corrosion, applied mathematics, modelling/simulation, and mechanical testing in order to carry out the given tasks successfully. The application of the inter-disciplinary knowledge of applied mathematics, simulation/modelling, materials selection, corrosion, design, and economics is seen in the solution options proposed by student M from group VII to re-design of the wind damaged signboard (Figure 2).

Hence, the rigorous and inter-disciplinary nature of case study is able to facilitate the development of conceptual understanding, analytical thinking, evaluation, optimisation, and problem formulation skills in the participants [8, 15, 16]. This finding could be attributed to the fact that (i) emphasis on syllabus was replaced with the establishment of learning outcomes; (ii) meetings, seminars, and presentations complemented formal lectures; and (iii) assessment was undertaken through a variety of complementary methods [2, 14].

Table 6 shows that the use of case study provided participants with similar goals as they work on a group project with the opportunity to direct their own learning process, develop leadership skills, and learn from one another within a team. Therefore, outcomes from this study have further confirmed that learning principles such as problem based learning, student directed learning, activity-based learning, and inter-disciplinary learning which are embedded in case study facilitate the development of conceptual understanding, analytical thinking, and team working skills in students [9, 17].

Table 6. Students' perception of the adoption of case-studies for teaching failure analysis

Likeness about case study	"I liked the fact that we visited the accident sites in my group, -----, to gather data for failure analysis. This was quite helpful in aiding one to think through the right questions to ask to determine the cause of failure and proffer solution for re-designing and re-manufacturing. All these activities helped me to relate information from lectures and text books to the reality."
Professional practice	"---- my involvement as a group leader as well as the presentation aspect of the case study assisted to develop confidence in my ability to lead and to talk with others. Realising as a leader that I need to defend my contribution to the group work helped me to summon courage to talk publicly. I hope to use these skills in marketing for a manufacturing company." "Working in my group also helped me to become familiar with other members of my class I had not talked to in the past. I got to know more about them, especially, their strengths as individuals. I'm happy that this experience had prepared me to work in a multi-cultural working environment in future."
Role of tutors	This case study is quite different from the lecture method because it provided opportunity for students to explore failure analysis through practical experience instead of have having a lecturer teaching something that would have been difficult to understand. The group meetings promoted frank discussion about failure analysis. I think students were able to master the learning process through case study of failure analysis while the lecturers facilitate the learning process."
Preference for case study or traditional lecture method	"I like this case study more than lecture method because it helped to appreciate the reality of failure analysis of engineering components and learn from other members of my group." "I like this case study of failure analysis because I was actively involved in all the activities such as planning, analysing, re-designing, and fabricating our damaged cutlass. It is actually better than the lecture methods where the lecturers just talk all through while we (students) only listen and talk less. Ummm, I'm happy with case studies; I could think through and understand failure analysis better than I would have done if only lecture notes were just dumped on me. Yeah! Doing stuff like this is good."
Dislike and suggestion for improvement	"This case study is too rigorous for me. It did not allow me to have time to study other subjects adequately. Should this case study be brought into other courses, it will create serious problems for students. The numbers of students in my group are too much as some were not just committed to the group goal with only half of the group working on the case study."

The use of assessment methodology which requires that students meet (i) regularly as a group to brainstorm; (ii) with their tutors to present their contribution to the group projects as well as demonstration of re-designed and re-manufactured components is seen to have promoted awareness and development of hands-on-skills (Figure 1), time management and planning skills (Table 4), communication skills, and ability to work in a multi-cultural working environment among students (Table 6). Finally, these outcomes confirm that the case study make learning more interesting and motivating for students while allowing them to relate to real world situations. This is similar to findings from [5, 11, 14, 18, 19] who reported that the rigorous nature of the case study brought real world problems to the classroom while it also helped students to improve on their communication skills, ability to think critically, and apply the concepts and skills learned in the course in comparison to traditional lecture approach.

5. Conclusions and Recommendation for future work

This study employed case-based approach to impart employable skills and conceptual understanding of failure analysis of engineering components into final year mechanical engineering students in a Nigerian University. The case-based approach developed took into account problem formulation, team working and communication skills, oral presentation, and the use of hands-on activities to manufacture working models. These aspects are integrally related to give the student a suitable learning environment for knowledge acquisition, and employable skills development. The case-based approach designed in this study facilitates the use of facilities already available in the University without requiring specialised ones. Consequent upon the implementation of the case-studies, students' conceptual understanding of failure analysis was enhanced while they also developed skills in independent critical thinking, formulation, analysis, optimisation and evaluation of the performance of their designs and communication of their ideas effectively. Students are more self-dependent and organised as they were able to schedule meetings and activities by themselves, and consult their tutors, through their own initiative. The use of hands-on activities enabled students to understand the subject in a different way from the traditional lecture because they believe these activities are suitable to motivate control learning. In the future, we aim to investigate various roles of tutors in facilitating greater student retention in case studies, the role of learning environments and resources in implementing case studies in mechanical engineering modules as well as comparison among case study approaches for mechanical engineering and case study approaches that integrate several engineering courses.

REFERENCES

[1] Heywood, J. (2005). *Engineering Education: Research and Development in Curriculum and Instruction*. Hoboken, New Jersey: John Willey and Sons, Inc.

[2] Stojcevski, A., and Fitrio, D. 2008. Project Based Learning Curriculum in Microelectronics Engineering. Paper presented at the 14th IEEE International Conference on Parallel and Distributed Systems (pp. 773-777). Melbourne, Vic.

[3] Holgado-Vicente, J. M. Gandia-Aguera, F; Barcala-Montejano, M. A; and Rodríguez-Sevillano, A. A. 2012. Project Based Learning activities as a means of adapting conventional curricula to the demands of the 21st century aeronautical engineer. Proceedings of the Global Engineering Education Conference (EDUCON), IEEE (pp. 1 – 5). Marrakech.

[4] Anderson, T., Torrens, R., Lay, M., & Duke, M. 2007. Experience with practical project based learning in a developing undergraduate engineering degree program. In Proceedings of the International Conference on Engineering Education (pp. 1-6). Coimbra, Portugal.

[5] Razali, R., and Zainal, D. A. P. 2013. Assessing students' acceptance of case-method in software engineering education –a survey. *Procedia - Social and Behavioral Sciences*, 93, 1562 –1568.

[6] Bandura, A. 1997. Self-efficacy and health behaviour. In: A. Baum, S. Newman, J. Wienman, R West, and C. McManus, eds. *Cambridge handbook of psychology, health and medicine*. Cambridge: Cambridge University Press.

[7] Mayer, R.E., 2007. (2 ed.) *Learning and Instruction*. Pearson, Thousand Oaks.
Raju, P.K., and Sankar, C. S. 1999. Teaching real-world issues through case studies. *Journal of Engineering Education,* 88(4), 501–508.

[8] Gibson, I. 2005. Designing projects for learning. In T. Barrett, I. Mac Labhrainn, and H. Fallon, eds. *Handbook of Enquiry & Problem Based Learning* (pp.27-35). Galway: CELT. Accessed at http://www.nuigalway.ie/celt/pblbook/ on 25 January, 2013.

[9] Rodrı´guez, J., Lavero´n-Simavilla, A., del Cura, J.M., Ezquerro, J.M., Lapuerta, V., and Cordero-Gracia, M. 2015. Project Based Learning experiences in the space engineering education at Technical University of Madrid. *Advances in Space Research*, 56, 1319–1330.

[10] Fernandez-Samaca, L., and Ramírez, J. M. 2010. An approach to applying Project-Based Learning in engineering courses. Proceedings of ANDESCON, 2010 IEEE (pp. 1 – 6). Bogota.

[11] Wongpreedee, K., Kiratisin, A., and Virutamasen, P. 2015. Entrepreneurial mindsets for innovative brand development: Case studies in jewellery education. *Procedia - Social and Behavioral Sciences*, 195, 2236 –2241.

[12] Gijselaers, W. H. 1996. Connecting Problem-Based Practices with Educational Theory. In L. Wilkerson & W. H. Gijselaers eds. *Bridging Problem-Based Learning to Higher Education: Theory and Practice,* (page 13 - 21). San Francisco: Jossey-Bass.

[13] Graaff, E. D., and Kolmos, A. 2003. Characteristics of Problem-Based Learning. *International Journal of Engineering Education,* 19(5), 657-662.

[14] Majeed, F. 2014. Effectiveness of case-based teaching of physiology for nursing students *Journal of Taibah University Medical Sciences*, 9(4), 289-292.

[15] Heron, J., 2000. Co-operative inquiry: research with rather than on people. In: P. Reason, H. Bradbury, eds. *Handbook of Action Research*, (page 27-49). Sage, London.

[16] Banks, J. 2004. *Handbook of Multicultural Education*. LEA: N.J. 167-201. Available from http://www.engr.washington.edu/caee/. Accessed on 15th June, 2013.

[17] Loyens, S.M. M., Jones, S. H., Mikkers, J., and van Gog, T. 2015. Problem-based learning as a facilitator of conceptual change. *Learning and Instruction*, 38, 34-42.

[18] Raju, P.K., and Sankar, C. S. 1999. Teaching real-world issues through the case study. *Journal of Engineering Education,* 88(4), 501–508.

[19] Garg, K., and Varma, V. 2007. A study on the effectiveness of case study approach in software engineering education. Proceedings of 20th Conference on Software Engineering Education and Training (pp. 309-316). Dublin, Ireland.