ASEAN JOURNAL OF ENGINEERING EDUCATION

VOLUME 5 ISSUE 1

Industrial and Management Systems Engineering program assessment based on the new ABET student outcomes

Article history
Received
25 March 2021
Received in revised form
5 May 2021
Accepted
14 May 2021
Published online
30 November 2021

Jawad S. A. Alhashemi, Ali Allahverdi* and Kanti Ranjan Sarkar
Department of Industrial and Management Systems Engineering
Kuwait University, Kuwait
*j.hassan@ku.edu.kw, *ali.allahverdi@ku.edu.kw, kanti.s@ku.edu.kw*

Abstract

The quality of engineering education has been improved by the accreditation criteria established by credentialing agencies. As a result, the Industrial and Management Systems Engineering program at Kuwait University has been maintaining accreditation by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology for over 15 years. Since the assessment process needs to be thorough and simple at the same time, this paper explains how the Industrial and Management Systems Engineering program at Kuwait University designed and implemented an efficient and effective process for the establishment and assessment of the new Student Outcomes required by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology. All the seven new Student Outcomes specified by Criterion 3 of the accreditation requirements are shown to be satisfied by using four different assessment tools, two of which are direct and the other two are indirect. All the results have been statistically verified by using hypothesis testing with a significance level of 0.01. The paper presents a simple and practical assessment method which can be used by other engineering programs that are in the process of implementing the new Student Outcomes.

Keywords: ABET, assessment, accreditation, industrial engineering program, student outcomes

1. Introduction

Quality plays an essential role in improving programs and systems across all types of organizations, e.g., service, finance, manufacturing, healthcare, and education. Samples of such systems and programs are the European Foundation for Quality Model (EFQM) (Doeleman, 2014); the Baldrige National Quality Program (BNQP) (Ah, 1990); Six Sigma (Krueger, 2014); the Balanced Scorecard (BSC) (Mendes, 2014), ISO 9000 Quality Management System (Park and Kang, 2011); the Customer Service Excellence (CSE) program (Vaerenbergh et al., 2014).

Utilizing quality in engineering education has been intensified in recent years because of the increase in global competitiveness, ease of communication and multicultural interaction, and the need of having better graduates (Patil and Codner, 2007).

The quality of engineering education has been increased by the accreditation criteria established by credentialing agencies. Samples include the Japan Accreditation Board of Engineering Education (JABEE), the Engineering Accreditation Council of Malaysia (EAC). the Accreditation Board for Engineering Education of Korea (ABEEK), and the Accreditation Board for Engineering and Technology (ABET) of the USA.

The Bologna Process has been helpful in the development of a mutual accreditation basis (Augusti, 2006), which lead to the establishment of the European Network for Accreditation of Engineering Education (ENAEE) (Augusti, 2007). The quality level of engineering education has also been deliberated in other nations, such as Nigeria (Agboola, 2013) and Jordan (Aqlan, 2010).

Engineering programs worldwide have been applying the ABET criteria in order to improve the quality of their programs. Examples include the chemical engineering program at Columbia University (Hilla, 2014), biomedical engineering program at Johns Hopkins University (Allen, 2013), petroleum engineering program at the United Arab Emirates University at Al-Ain (Abu-Jdayil, 2010), mechanical engineering program at Kuwait University (Christoforou, 2008), electrical engineering program at American University of Sharjah (Al-Nashash, 2009) and at Texas A&M University-Texarkana (Morsy et al., 2020), industrial engineering program (Aldowaisan and Allahverdi, 2015, Allahverdi and Aldowaisan, 2015) at Kuwait University, and computer engineering program at Umm Al Qura University (Rashid, 2021), to name a few.

An engineering program requesting to be accredited by the Engineering Accreditation Commission of ABET must establish that it satisfies all the ABET criteria. One of ABET's criteria is related to Student Outcomes (SOs). ABET defines the student outcomes as "Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program" (ABET, 2019 – 2020).

From the literature review, it can be seen that there is a need for a clear, simple, and efficient assessment process of the SOs that is also deep, thorough, and effective in order to gain knowledge of the quality of the educational program and its graduates.

In this paper, we show how the Industrial and Management Systems Engineering (IMSE) program at Kuwait University (KU) satisfies the ABET requirement on the new SOs (1 to 7) based on assessment data from the past five years. These SOs are presented and discussed in section 2. Then, section 3 defines the design and application of an efficient process for the establishment and assessment of SOs at the IMSE program of KU. Next, in section 4, all the seven new SOs, specified by ABET, are shown to be satisfied by each of the four different assessment tools utilized. In section 5, the results have been statistically verified. Finally, concluding remarks are presented in section 6.

2. Student Outcomes

The IMSE program at KU has adopted the ABET's Student Outcomes (SOs) 1 to 7. The seven SOs described below are the same as those listed under Criterion 3 of ABET's general criteria for accrediting engineering programs (ABET, 2019 – 2020).

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. an ability to communicate effectively with a range of audiences.
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Prior to the adoption of the revised SOs (1 to 7), the IMSE program at Kuwait university had its SOs based on ABET's old SOs (a to k). The old SOs (a to k) were utilized/assessed until Spring 2018. The assessment of the new SOs (1 to7) has started in Fall 2018 based on a mapping between the new seven SOs (1 to 7) and the old eleven SOs (a to k). The mapping of the new SOs (1 to 7) and the old SOs (a to k) are given in Table 1.

Table 1: Mapping between new SOs and old SOs

Old SOs (a to k)	New SOs (1 to 7)
a, e	1
c	2
g	3
f, h, j	4
d	5
b	6
i	7
k	Implied in 1, 2, 6

This section describes the design and implementation of a systematic process for the assessment of SOs. Four different assessment tools are used to measure performance against specified attainment levels for each SO.

Table 2 shows the IMSE curriculum alignment with the new SOs (1 to 7) which are classified as general education, basic engineering, IMSE requirements, Industrial engineering electives, engineering management electives and Non-IMSE requirements. The symbol R is used to denote significant *Relevance* between the course and the SO.

It is important to note that the SOs marked for each course are directly related to the learning objectives of that course. Therefore, the chosen assessment methods to measure the realization of SOs in essence lead to the assessment of learning objectives as well.

Table 2: IMSE curriculum alignment with revised SOs 1 to 7

Course No.	Courses	Student Outcomes						
No.	**General Education**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
	Humanities and Social Science Electives				R			
	English Language Courses			R				
	Math and Science Courses and labs	R						
Course No.	**Basic Engineering Requirements**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
600-104	Engineering Graphics			R				
600-205	Electrical Engineering Fundamentals	R						
600-207	Electrical Engineering Fundamentals Lab	R					R	

600-208	Engineering Thermodynamics	R			R			
600-209	Engineering Economy	R			R			
600-304	Engineering Probability and Statistics	R						
600-307	Applied Numerical Methods and Programing for Engineers	R						
Course No.	**Other Engineering Requirements**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
600-102	Workshop				R		R	
600-202	Statics	R						
Course No.	**IMSE Requirements**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
660-221	Introduction to Industrial Engineering	R		R	R	R	R	R
660-312	Industrial Engineering Labs			R	R	R	R	
660-321	Work Design & Measurements	R	R		R		R	
660-325	Safety and Health for Engineers			R	R	R	R	R
660-351	Engineering Statistical Analysis	R					R	
660-352	Production Cost Analysis	R			R			
660-361	Operation Research I	R	R					R
660-371	Engineering Management			R	R	R		
660-372	Project Management & Control	R		R	R	R		R
660-434	Facilities Planning & Design	R	R	R				
660-454	Production Planning & Inventory Control	R	R					
660-457	Quality Control	R			R		R	R
660-461	Operation Research II	R						
660-481	Systems Simulation	R	R	R		R	R	R
660-496	Design in Industrial Engineering	R	R	R	R	R	R	R
Course No.	**Non-IMSE requirements**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
650-312	Petroleum Industry	R						
630-241	Material Science and Metallurgy	R						
630-353	Manufacturing Processes	R						
Course No.	**Industrial Engineering Electives**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
660-395	Industrial Engineering Internship	R		R	R	R		
660-419	Special Topics in Industrial Engineering	R						
660-425	Human Factors Engineering		R	R	R	R	R	R
660-429	Ergonomics and Safety in Process Industry		R	R	R	R		
660-445	Manufacturing Systems	R	R		R			
660-446	Computer Aided Manufacturing	R	R					
660-451	Reliability and Maintainability Engineering	R	R		R		R	
660-456	Productivity Improvement Methods	R	R		R	R		
660-458	Design of Experiments	R	R	R		R	R	
660-464	Optimization Methods	R						
660-487	Expert Systems in Industrial Engineering	R	R	R		R		
660-494	Industrial Engineering in Process and Service Systems	R	R	R	R	R	R	
Course No.	**Engineering Management Electives**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
660-381	Data and Decision Analysis	R					R	
660-459	Quality in Health Care	R	R	R	R	R		
660-470	Supply Chain Management	R	R		R	R		R
660-473	Quality Management and Organizational Excellence		R	R		R		
660-474	Accounting and Finance for Engineering	R		R	R	R		
660-475	Engineering marketing Analysis		R		R		R	
660-477	Entrepreneurship and Innovation		R	R	R	R	R	
660-479	Law for Engineers		R		R			
660-489	Special Topics in Management Systems Engineering	R						

3. Assessment Design and Implementation

The IMSE program regularly assesses and evaluates the extent to which the program Student Outcomes (SOs) are being attained. Figure 1 shows the process of SOs evaluations and illustrates how all the assessment tools are used within the assessment process flow.

The assessment process of the SOs is generally handled through a series of steps that starts with the assessment secretary who receives the assessment data generated from the assessment tools. Then, the data is analyzed and presented to the Undergraduate Program Committee (UPC) which evaluates the results of the analysis and recommends actions to the department chairman. The chairman then introduces relevant recommendations to the department council, which makes the final recommendations. Once these recommendations are approved by the council, they are communicated for implementation by the chairman to the relevant party either inside or outside the department.

Table 3 lists all four assessment tools used for the SOs assessment along with the responsible party, assessor, and the assessment usage frequency of each tools.

The "Instructor Class Evaluation" is administered by the College of Engineering and Petroleum (CEP); where each faculty member completes the form at the end of each semester for each course. The faculty member evaluates the students' performance in relation to the course's relevant outcomes using a scale of 1 to 5; where 1 = very weak, 2 = weak, 3= satisfactory, 4 = very good, and 5 = excellent performance.

The "Exit Survey" is also administered by the CEP; where each graduating student is required to complete the form. In addition to questions related to SOs, the survey asks other questions related to future plans, assessment of the learning environment at KU, assessment of the support services at KU, and general assessment. It should be noted that the survey questions related to the SOs do not match with the exact wording of the defined SOs but they clearly map to them.

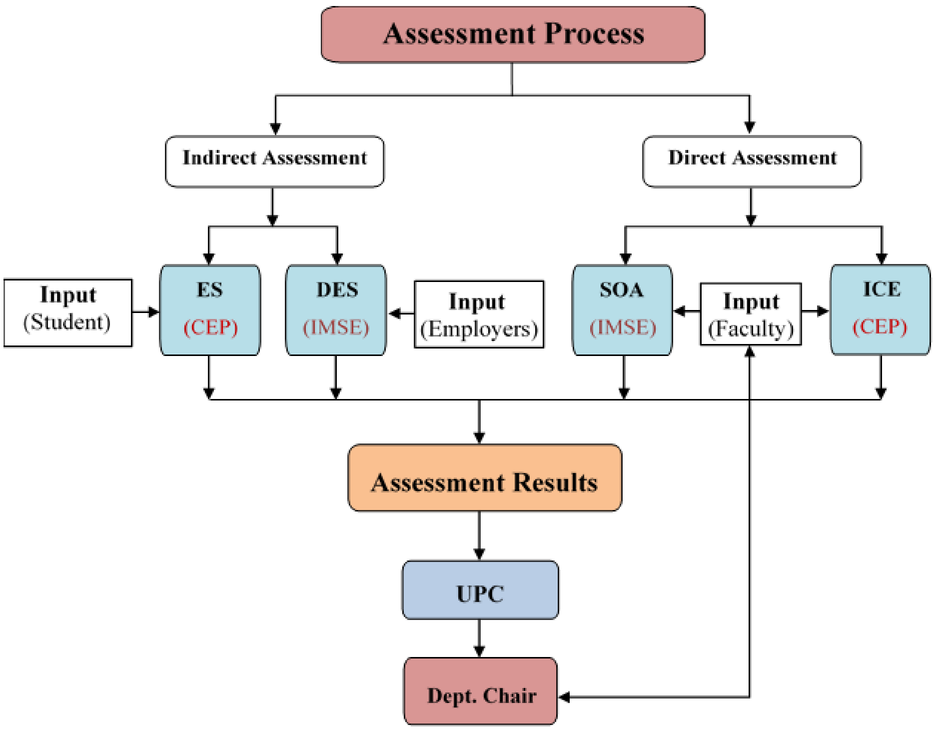


Figure 1: The assessment process of development, evaluation, and improvement of the SOs

Table 3: Assessment tools used in the evaluation of SOs

Assessment Tools	Conducted by	Assessor	Measurement Method	Frequency
Instructor Class Evaluation (ICE)	CEP	Faculty	Direct	Every Semester
Exit Survey (ES)	CEP	Student	Indirect	Every Year
Student Outcome Assessment (SOA)	IMSE	Faculty	Direct	Every Semester
Design in Industrial Engineering - Employer Survey (DES)	IMSE	Employer	Indirect	Every Semester

The "Student Outcome Assessment" is administered by the Industrial and Management Systems Engineering (IMSE) department. This form is completed for selected outcomes relevant to the course by the faculty members. The score for each outcome reflects the average quantitative direct measurement of the students' performance on the relevant assignments. The assignments might include homework, exams, quizzes, projects, and presentations.

The "Design in Industrial Engineering – Employer Survey" is also administered by the IMSE department. In this course (0660-496), students are divided into groups to work in a selected organization where each group is assigned to a department or a division and supervised by professional top-level personnel from that department. The students frequently visit the organization to identify problems, collect data, perform analysis, and propose solutions. At the conclusion of the course, students give two final presentations; one to the faculty members and a second to the public where company representatives are present. The employer survey is completed by the company supervisors, where they express their assessment of the students' achievement of the SOs.

The tools ES and DES can be considered as indirect measures since they are essentially surveys. However, the ICE and SOA tools are direct measures where the instructor assesses students directly based on their achievements on some specific outcomes.

The expected level of attainment for each SO when using each one of the four assessment tools is set at 60%. This attainment level may be reconsidered periodically for the possibility of raising the level of expectation.

4. Assessment Results

As stated earlier, the new ABET SOs (1 to 7) were adopted for use starting from the academic year 2018-2019. Before that, the old ABET SOs (a to k) were being used. Thus, in order to have a fair comparison of the SOs over the academic years from 2014-2015 to 2018-2019, the results of the four assessment tools (ICE, SOA, ES and DES), which were based on the old ABET SOs (a to k) for the academic years 2014-2015 to 2017-2018, were converted to the new ABET SOs (1 to 7) using the mapping given in Table 1. These results are summarized in Tables 4 to 7. The values in these tables represent the average evaluation scores of all assessors of the specified SOs in a given academic year. The results in the tables show that all SOs on average exceed the satisfactory level of 60%. In fact, all the scores are above 70%. Also, the standard deviation is in the single digits, which indicates a generally small level of variation.

Table 4: Results of the attainment of SOs using ICE

	ICE							
	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019		
New SOs	S14	F14-S15	F15-S16	F16-S17	F17-S18	F18-S19	Avg.	SD.
1	77.9%	78.6%	78.3%	78.6%	77.6%	80.0%	78.5%	0.82
2	80.0%	85.2%	75.5%	77.4%	77.3%	78.8%	79.0%	3.37
3	78.0%	82.5%	80.5%	77.7%	83.5%	83.9%	81.0%	2.72
4	71.8%	74.7%	75.0%	70.2%	76.5%	78.0%	74.4%	2.90
5	75.6%	81.7%	85.0%	78.5%	87.5%	86.8%	82.5%	4.79
6	76.0%	71.8%	79.5%	78.2%	73.6%	77.8%	76.1%	2.96
7	66.0%	71.5%	74.0%	72.5%	77.2%	82.8%	74.0%	5.65

Table 5: Results of the attainment of SOs using SOA

	SOA							
	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019		
New SOs	S14	F14-S15	F15-S16	F16-S17	F17-S18	F18-S19	Avg.	SD.
1	78.4%	79.2%	82.1%	83.7%	81.7%	86.0%	81.8%	2.82
2	86.0%	77.1%	83.1%	83.6%	80.9%	90.9%	83.6%	4.68
3	87.0%	83.3%	88.3%	84.6%	81.9%	86.4%	85.2%	2.40
4	84.1%	83.6%	84.6%	82.7%	88.3%	83.2%	84.4%	2.01
5	81.1%	82.7%	91.9%	85.2%	82.5%	88.0%	85.2%	4.09
6	76.4%	80.0%	85.1%	83.6%	85.2%	90.0%	83.4%	4.71
7	84.0%	79.7%	86.3%	81.4%	82.2%	88.5%	83.7%	3.25

Table 6: Results of the attainment of SOs using ES

	ES							
New SOs	2013 -2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	Avg.	SD.
1	84.0%	77.4%	81.5%	81.0%	78.4%	81.3%	80.6%	2.39
2	82.0%	79.7%	77.8%	79.0%	75.6%	78.2%	78.7%	2.12
3	82.0%	78.0%	81.0%	83.0%	74.3%	82.9%	80.2%	3.43
4	80.7%	78.0%	79.0%	78.7%	78.1%	79.7%	79.0%	1.02
5	88.0%	80.0%	82.0%	80.0%	82.5%	88.3%	83.5%	3.78
6	80.0%	77.9%	79.0%	76.0%	76.1%	80.3%	78.2%	1.87
7	80.0%	77.0%	75.0%	75.0%	77.5%	85.0%	78.2%	3.79

Table 7: Results of the attainment of SOs using IMSE 496: design in IE - employer survey

	DES							
SO's	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	Avg.	SD.
	S14	F14-S15	F15-S16	F16-S17	F17-S18	F18		
1	96.7%	85.6%	91.7%	84.3%	93.3%	86.7%	89.7%	4.91
2	93.8%	80.0%	85.0%	90.8%	95.0%	100.0%	90.8%	7.23
3	100.0%	93.3%	80.0%	90.0%	90.0%	90.0%	90.6%	6.47
4	95.8%	86.7%	63.3%	95.8%	86.7%	93.3%	86.9%	12.29
5	100.0%	93.3%	95.0%	93.3%	90.0%	90.0%	93.6%	3.71
6	96.3%	80.0%	90.0%	86.7%	85.0%	83.3%	86.9%	5.67
7	95.0%	93.3%	85.0%	85.0%	70.0%	85.0%	85.6%	8.86

Next, the ICE, SOA, and ES assessment tools are compared relative to each SO. The DES assessment tool is not included since it addresses only one course and its SO attainment results are generally very high (above 80%). It is worth mentioning that the ES is a typical assessment tool that is used by all programs at KU and almost all schools worldwide. Moreover, the ICE is used by all the departments at the college of Engineering and Petroleum at KU whereas the SOA is uniquely utilized by the IMSE department at KU only.

The assessment results for all SOs (1 to 7) are shown in Figures 2 to 8. The figures demonstrate that the threshold value of 60% is exceeded for each of the assessment tool results (ICE, SOA, and ES) from Spring 2014 to Fall 2018.

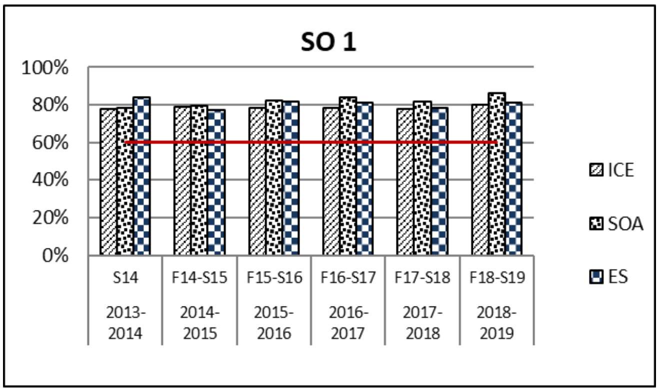


Figure 2: SO 1

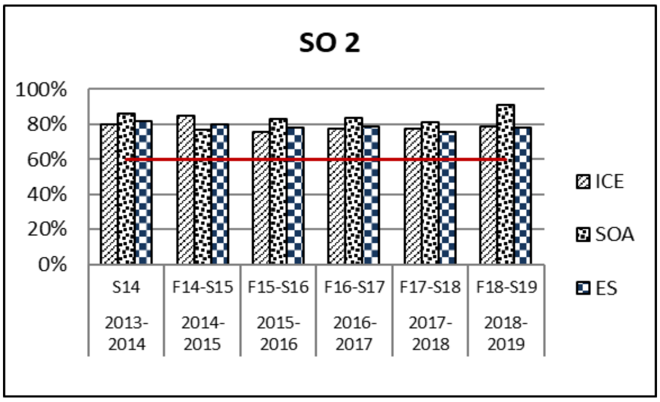


Figure 3: SO 2

As seen in Figure 2 for SO 1, the results of all three assessment tools are close to each other. This indicates that the students have achieved a satisfactory competence in SO 1 at the end of their study. Moreover, the SOA and ICE results show that both have almost leveled in all the years indicating that the actual performance as measured by the instructors agrees with the perception of the students with regard to this outcome.

Figure 3 shows that the SOA and ICE results are consistent with regard to this outcome. The ES results are also comparable with the others.

Communication is a key tool for success in academia as well as in post-graduation endeavors. In Figure 4, the threshold value of 60% is remarkably exceeded in all evaluations from Spring 2014 to Spring 2018. The SOA and ICE results inform that the actual performance as measured by the instructors have achieved the satisfactory level. However, the students' perception regarding this outcome was higher. Moreover, ES results indicate satisfactory level of achievement of this outcome.

The ethical and professional responsibility is one important outcome that is considered by the IMSE. The results in Figure 5 exceeded the threshold value of 60% in all evaluations from Spring 2014 to Spring 2018. The SOA and ICE results show that the SOA results are consistently higher than those of ICE. On the other hand, the ES feedbacks are consistent over the years.

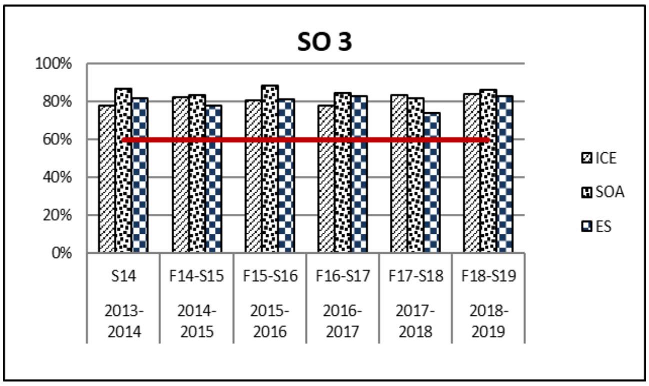


Figure 4: SO 3

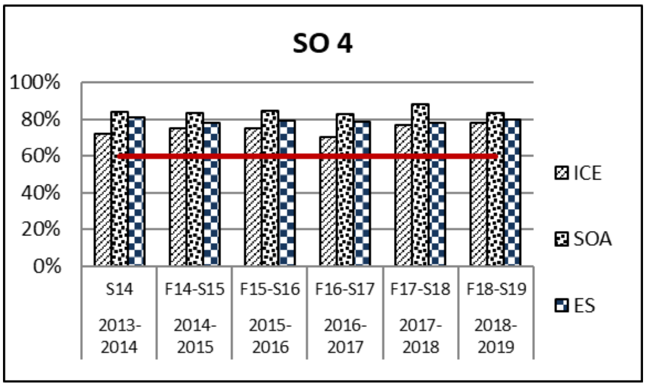


Figure 5: SO 4

For SO 5, the results demonstrated that the threshold of 60% is consistently exceeded from Spring 2014 to Spring 2018. The SOA and ICE results inform that the SOA results seem to be higher in all the years except academic year 2017-2018 indicating that the actual performance of the students have achieved the satisfactory level. While an alternating pattern can be observed in Figure 6 in the three tools, a satisfactory level is still achieved by all of them.

The results for SO 6 in Figure 7, which is related to the ability to develop and conduct appropriate experiments, analyze and interpret data and use engineering judgement to draw conclusions, show that the 60% threshold value has been exceeded in all evaluations from Spring 2014 to Spring 2018. The SOA and ICE results demonstrate that the SOA seems to be higher in all years indicating that the actual performance as measured by the instructors agrees with the perception of the students with regard to this outcome. Moreover, the ES results seems to be lower than the SOA results in last few years.

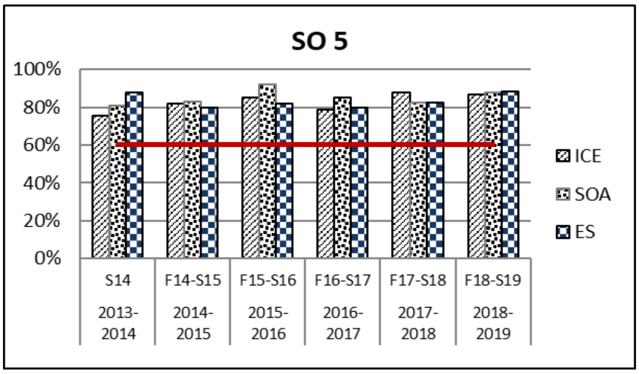


Figure 6: SO 5

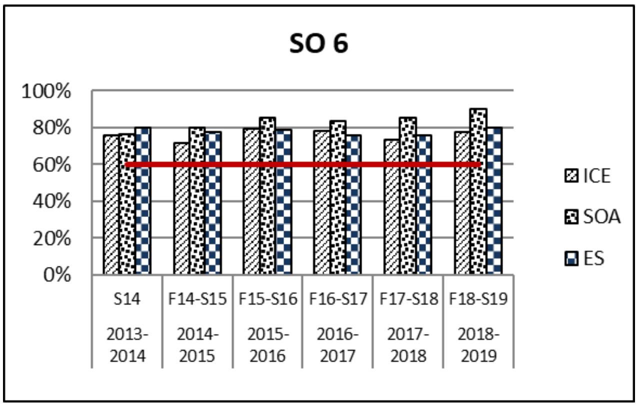


Figure 7: SO 6

In Figure 8 the ICE results show that it remained almost at the same level in the past two academic years with a value around 75%. However, the SOA outperforms the ICE indicating that the actual performance of the students is higher than that set by the instructors regarding this outcome. Moreover, the ICE, SOA and the ES exhibit the same pattern within each academic year with the SOA being the highest.

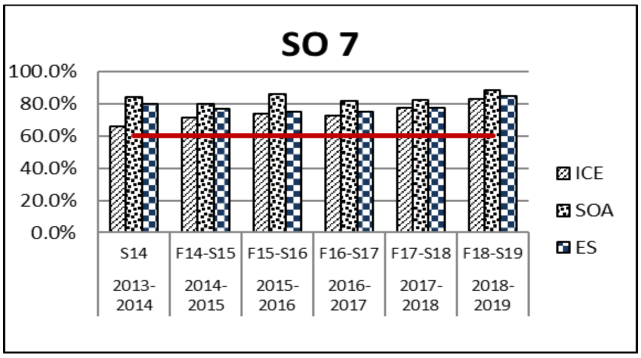


Figure 8: SO 7

5. Statistical Analysis

As stated earlier, the expected level of attainment for each student outcome is 60%. In this section, we conduct tests of hypotheses to statistically verify the results obtained in the previous section. We conduct test of hypothesis for each of the assessment tools of SOA, ES, DES, and ICE for the combined six academic years considered, i.e., 2013-2014, 2014-2015, 2015-2016, 2016-2017, 2017-2018, 2018-2019.

A two-sample t-test is performed for each of the assessment tools to statistically verify that the SOs on the assessment tool exceeds the excepted level of 60%. The following four sets of hypotheses were performed.

Set 1 H_0: $\mu(SOA) = 60\%$

H_1: $\mu(SOA) > 60\%$

Set 2 H_0: $\mu(ES) = 60\%$

H_1: $\mu(ES) > 60\%$

Set 3 H_0: $\mu(DES) = 60\%$

H_1: $\mu(DES) > 60\%$

Set 4 H_0: $\mu(ICE) = 60\%$

H_1: $\mu(ICE) > 60\%$

where $\mu(.)$ shows the average SO value over the six semesters considered for each of the assessment tools of SOA, ES, DES, and ICE. The null hypothesis (H_0), for each of the four sets, was rejected at a significance level of 0.01. Therefore, the each SO value statistically exceeds the expected level of attainment of 60% for each of the assessment tools of SOA, ES, DES, and ICE for a significance level of 0.01.

6. Conclusions

A framework model was developed and implemented for Student Outcomes (SOs) for the Industrial and Management Systems Engineering program at Kuwait University by using a set of four assessment tools. These tools are the Instructor Class Evaluation (ICE), Student Outcome Assessment (SOA), Exit Survey (ES), and Design in Industrial Engineering – Employer Survey (DES). The tools ES and DES can be considered as indirect measures since they are essentially surveys. However, the ICE and SOA tools are direct measures where the instructor assesses students directly based on their achievements on some specific outcomes. The tools were used to measure the attainment levels of each of the seven new Student Outcomes (SOs) specified by ABET. It has been shown that each of the SOs exceeds the established threshold value by each of the utilized four assessment tools. The results were statistically confirmed using tests of hypotheses with a significance level of 0.01. Since the presented assessment method is both efficient and effective, it can be used by other engineering programs that are in the process of implementing the new SOs of ABET.

References

ABET, Accreditation Board for Engineering and Technology (ABET), Criteria for Accrediting Engineering Programs, 2019 – 2020. Available online at: http://www.abet.org.

Abu-Jdayil, B. A. (2010). Curriculum assessment as a direct tool in ABET outcomes assessment in chemical engineering program. European J. of Eng. Educ., 35, 489-505.

Agboola, O. E. (2013). Accreditation of engineering and architectural education in Nigeria: the way forward. Proc. 2nd World Conf. on Educational Technol. Research, 836-840.

Ah, J. (1990). Using the Malcolm-Baldrige-national-quality-award criteria to assess a company quality program. TAPPI J., 73, 293-294.

Aldowaisan, T., Allahverdi, A. (2015). Continuous improvement in the Industrial and Management Systems Engineering Program at Kuwait University. European J. of Eng. Educ, 41, 369-379.

Allahverdi, A., Aldowaisan, T. (2015). Assessment of student outcomes of the industrial and management systems engineering program at Kuwait University. Global J. of Eng. Educ., 17, 103-112.

Allen, R. A. (2013). Sharing best practices in teaching biomedical engineering design. Annals of Biomedical Eng., 41, 1869-1879.

Al-Nashash, H. K.-A.-T. (2009). M., Improving electrical engineering education at the American University of Sharjah through continuous assessment. European J. of Eng. Educ., 34, 15-28.

Aqlan, F. A.-A.-H. (2010). Quality assurance and accreditation of engineering education in Jordan. European J. of Eng.. Educ., 35, 311-323.

Augusti, G. (2006). Transnational recognition and accreditation of engineering educational programs in Europe: perspectives in a global framework. European J. of Eng. Educ., 31, 249-260.

Augusti, G. (2007). Accreditation of engineering programs: European perspectives and challenges in a global context. European J. of Eng. Educ., 32, 273-283.

Christoforou, A. a. (2008). Improving teaching and learning in engineering education through a continuous process. European J. of Eng. Educ., 33, 105-116.

Doeleman, H. t. (2014). Empirical evidence on applying the European Foundation for Quality Management Excellence Model, a literature review. Total Quality Manage. and Business Excellence, 25, 439-460.

Hilla, M. B. (2014). The future of chemical engineering design: impact of faculty makeup and industrial needs. Computer Aided Chemical Eng., 34, 88-97.

Krueger, D. P. (2014). Six Sigma implementation: a qualitative case study using grounded theory. Production Planning and Control, 25, 873-889.

Mendes, P. N. (2014). Quantitative performance targets by using balanced scorecard system: application to waste management and public administration. Waste Manage. and Research, 32, 927-936.

Morsy, M., Irizarry, K., Rauf, F., Reavis, D. (2020). Charting New Waters: Curriculum Improvement in the Light of Applicable ABET-EAC Criteria Beginning in the 2019-2020 Cycle. International J. of Eng. Educ., 36, 1009-1017.

Park, D.J., Kang, I.S. (2011). The study of follow-up audit compliance for quality management system in subcontractors of shipbuilding industry based on ISO 9000 requirements changes. Journal of Korea Safety Manage. and Science, 13, 161-169.

Patil, A., Codner, G. (2007). Accreditation of engineering education: review, observations and proposal for global accreditation. European J. of Eng. Educ., 32, 639-651.

Rashid, M. (2021). A Systematic Approach of Data Preparation for ABET Accreditation. International J. of Eng. Educ., 37, 172-184.

Vaerenbergh, Y.V., Keyser, A.D., Lariviere, B. (2014). Customer intentions to invoke service guarantees, do excellence in service recovery, type of guarantee and cultural orientation matter? Managing Service Quality, 24, 45-62.

Understanding and Correlating of Chemical Engineering Thermodynamics I and Process Heat Transfer through Integrated Project

Article history
Received
9 February 2021
Received in revised form
10 June 2021
Accepted
11 June 2021
Published online
30 November 2021

Shafirah Samsuri *, Shuhaimi Mahadzir, Wan Nur Aisyah Wan Osman
Department of Chemical Engineering, Universiti Teknologi PETRONAS,
32610 Seri Iskandar, Perak, Malaysia
** shafirah.samsuri@utp.edu.my*

Abstract

The development of engineering education plays a significant role in creating a competency base for engineering students to be excellent in engineering practice as well as other professional skills such as communication, teamwork and leadership. Project-Based Learning via Integrated Project entitled Heat Recovery from Ammonia Synthesis Reactor for Power Generation was introduced as a new learning approach for First Year First Semester Chemical Engineering student to replace the conventional learning approach via lecture. This integrated project is a hybrid of two core Chemical Engineering subjects for First Year students: Chemical Engineering Thermodynamics I and Process Heat Transfer. This integrated project aims to evaluate students' ability to relate two different subjects when learning in the same semester and apply them to the same application. This integrated project is expected to enhance students' learning curve and ensure that the output of this study can be achieved in a consistent effort and timely manner. Assessments in formative (reflection and peer review) and summative (final report) are applied to the students via individual and group. Based on the reflection's analysis, 50% of the students mentioned that the project is very challenging; meanwhile, only 30% agreed that they could relate the project with both subjects even though it is complex and challenging. Despite that, 70% of the students stated that their learning goal is achievable. They were able to view the industrial application, especially the heat exchanger application, through this project. Overall, 90% agreed that they achieved this integrated project's objectives: to relate two different subjects when learning in the same semester and apply them to the same application. Hence, it is noteworthy to highlight that this integrated project is carefully mapped. The new learning approach via Project-Based Learning brought positive outcome towards the students' learning experiences, skills and understanding.

Introduction

Engineers must have interpersonal, communication, and management skills to be flexible in dealing with the public, exposed to global scenarios, and effectively facing current and future challenges. In Malaysia, the engineering education model is expected to train future engineers to be excellent in engineering practice and great leaders, including strengthening scientific knowledge and professional skills. It is a competency base for engineering students to achieve global recognition and accreditation as capable engineers and leaders (Megat Mohd Noor et al., 2002). Therefore, educators play essential roles in providing effective yet efficient teaching and learning approaches for those students.

Most engineering students could not relate to the courses they learned and could not apply the knowledge in actual applications; hence, they would limit themselves to solve complex engineering problems and problems in the industry. Problems, especially in industry, need to be solved quickly and cost-effectively; thus, project-based learning encourages students to develop practical design thinking and problem-solving skills, especially throughout their undergraduate studies, to be great engineers and leaders future. The traditional learning approaches of using lectures are ineffective (Aziz et al., 2013; Lukman et al., 2013; Mamat & Mokhtar, 2008); hence the transformation from those conventional learning are needed.

Moon et al. (2007) proposed a better learning approach where the students can participate actively and relate to real-life situations. This is where project-based learning came to light to replace traditional learning approaches (Azizan et al., 2018). Unlike the conventional teaching method, the lecturers prepare a related problem statement and guide the students (Tatar and Oktay, 2011). According to Nielsen (2003), the first and only university built in 1974 on project-based learning implementation was Aalborg University, located in Denmark. Project-based learning is a new learning approach introduced to create more engaging learning environments while increasing the students' interest and improving their grades and skills aligned with the new era of the 4th Industry Revolution to create intelligent industries.

In addition, Jumaat et al. (2017) support the implementation of project-based learning to enhance the learning journey of students, especially in terms of constructivism point of view. Theoretically, constructivism is defined as a learning theory where students created their understanding based on their knowledge and experience (Glaser & Resnick, 2016). In the 1900s, Dewey (1916) mentioned that learning should become an active constructive approach instead of a passive absorption method. Furthermore, Biggs (2003) suggested that constructive alignment is the best approach to optimize the learning quality. By definition, 'constructive' is where the student is the one who should construct the learning and actively participate in the learning activities, while 'alignment' is where the teacher needs to align with the learning activities as they need to provide the best environment which could achieve desired learning outcomes (Biggs, 2003). This is in line with the statement made by Tyler (1989) where "Learning takes place through active behaviour of the student, it is what he does that he learns, not what the teacher does".

Hence, project-based learning comes forward as the best approach to reflect the constructivism theory as it required a practice where the student needs to complete the task based on real-world situations. This approach is denoted as the student-centred approach as students are the ones who need to be responsible for exploring critical knowledge and meaningful experience through series of learning activities (Kelly, 2014). According to Helmi et al. (2020), student-centred approaches allow students to be active throughout their learning journey. This approach seems important to ensure that students have enough knowledge and experience to face real-life situations, especially in this century. The world is currently facing a new pandemic known as Covid-19, which required many transformations in skills, especially for professionals, including engineers. Hence, conventional learning through lectures cannot be comprehended, but more student-centred learning approaches need to be introduced. Moreover, this approach also requires students to find the solution via hands-on investigation that needs to be done in a group (collaborative environment) (Yam & Peter, 2010). Hence, by introducing this approach, student at the same time able to strengthen their knowledge and improve their professional skills.

In 2009, Reaburn et al. (2009) conducted a study to redesign the undergraduate course by focusing on student interaction and engagement throughout the learning process. Generally, the concept of constructive alignment was applied for the undergraduate course was redesign. From the result, it was found out that the study successfully achieved the objective where student interaction and engagement was improved in terms of learning and assessment tasks. Meanwhile, in 2017, Aziz et al. (2017) introduced a real-world problem for a Chemical Engineering student in the First Year from Universiti Teknologi Malaysia (UTM), where integration of three pillars of sustainable development (Environment, Economic and Social) was used. They claimed that the problem related to industry made the problem more realistic and increased the students' exposure to real-life situations. Similar approach was introduced in this study which involves the concept of project-based learning via an Integrated Project entitled Heat Recovery from Ammonia Synthesis Reactor for Power Generation. From the definition of project-based learning, students are challenged to develop a plan and create a product that addresses the problem. Like this integrated project, in this study, students were required to design a power plant generated from the recovered heat of ammonia synthesis reactor. This approach covers two core Chemical Engineering subjects in First Year curriculum: Chemical Engineering Thermodynamics I and Process Heat Transfer. These subjects are compulsory for Chemical Engineering students to learn. For this project, some research questions were considered in enhancing the students' studies:

- How can the project help the students to learn innovatively?
- How to develop a project that can encourage the students to seek the project's succession?
- How can the project help the students to relate two different courses together?
- What are the students' responses to the project?

Integrated Design Implementation

Integrated Project in this study is used to maximize the students' knowledge in relating two different subjects when they learn it in the same semester and help the students apply those two different subjects towards the same application. In this study, the integrated project is one hybrid project that combines two core Chemical Engineering subjects: Chemical Engineering Thermodynamics I and Process Heat Transfer in a single project for First Year Chemical Engineering student in their third semester. The implementation of project-based learning in this integrated project is illustrated in Figure 1. All assessment, such as the final report was done in the group, while the reflection and peer review were based on the individual. The reflection and peer review were done to observe the students' feedback to motivate them and make their learning journey more enjoyable.

The project is expected to enhance students' learning curve and make sure that the output of this study can be achieved in a consistent effort and timely manner. The project is run for one semester only and compulsory for the students in that semester. Eleven students were divided into a small team of 3–4 students per group. Universiti Teknologi PETRONAS (UTP) has three intakes per year: January, May, and September. All of these students in this study were from the January intake. This batch has small number of students as they are usually students who took foundation or diploma in other institutions. The May and September student intakes are the ones with the most number of students enrolled as most of them undergo Foundation in Engineering courses in UTP.

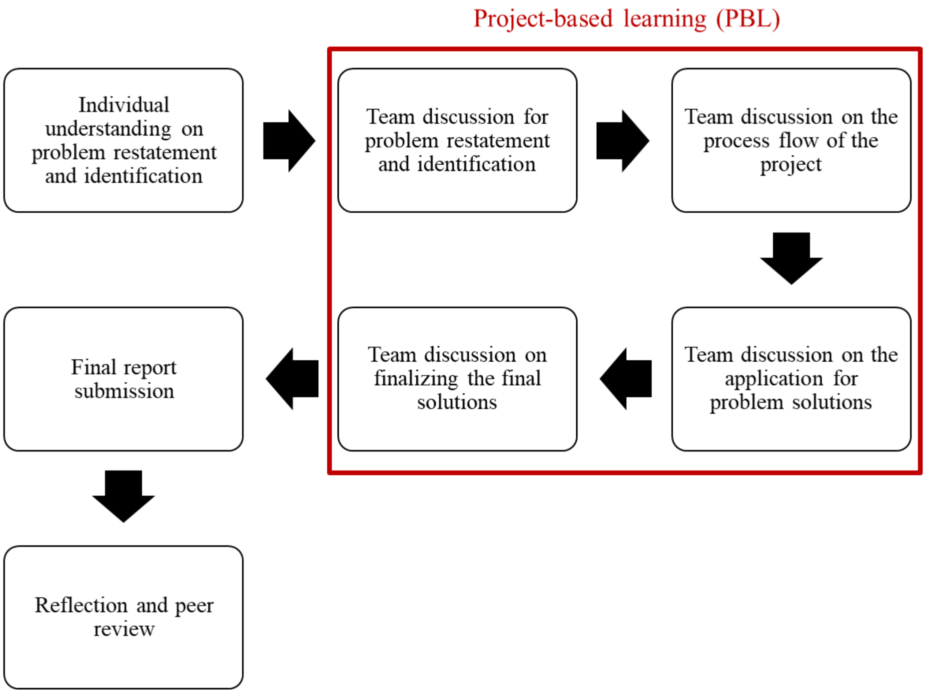


Figure 1. Process Flow for Integrated Project entitled Heat Recovery from Ammonia Synthesis Reactor for Power Generation with the implementation of Project-Based Learning

Assessments in formative (reflection and peer review) and summative (final report) are applied to the students via individual and group. The integrated project is in line with the constructive alignment framework. The appropriate assessments were designed from the course learning outcomes such as project report, peer rating, and reflection. The teaching and learning activities were prepared from these designed assessments, such as lectures, tutorials, an adjunct lecture from industry and additional online consultation session. Table 1 shows the course learning outcome related to the project.

Table 1. Course learning outcome

Course	Course learning outcome
Chemical Engineering Thermodynamics I	Perform related calculations and apply them in various thermodynamics systems.
Process Heat Transfer	Design and evaluate the performance of heat exchange devices.

Through this integrated project, only one problem statement is given on one application in week 4, and the students need to solve the problem in a team. The purpose is to evaluate the students fairly. An Aspen HYSYS simulation file containing an ammonia reactor was provided to the students. The students are required to use the given reactor effluent stream to execute the project tasks. The students are responsible for gathering information, evaluating the resources, solving the problem, and discussing the solution. The detail on the specific tasks assigned to the students is illustrated in Figure 2. This integrated project helped the student relate and apply two subjects in one application and encouraged them to improve their soft skills such as communication, teamwork, and leadership.

A special online session using Microsoft Teams was conducted to guide the students in completing the project. The lecturers and students previewed the problem statement and discussed the content critically. Students were free to ask questions and were given feedbacks or suggestions by their lecturers. The lecturers facilitated and coached the students along the task throughout the semester. An illustration of the suggested power plant was drawn to guide the students with their proposed design. During the class session, the progress of the project needs to be explained to the lecturers. There were a total of two sessions (2 hours per session) for each subject (Chemical Engineering Thermodynamics I and Process Heat Transfer) per week. All online session were recorded, and the lecturers and students were free to access the recorded videos in Microsoft Stream. From there, the lecturers can again provide feedback and keep track on their progress.

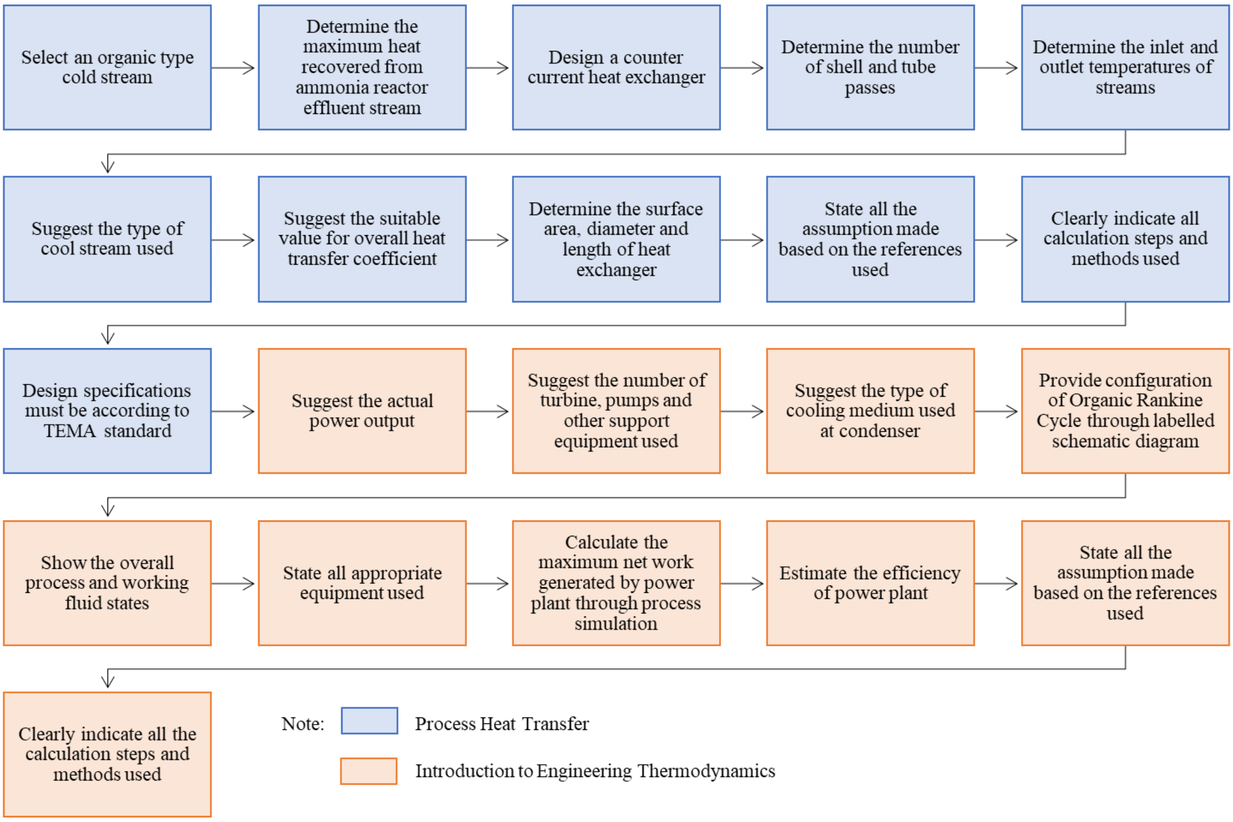


Figure 2. Specific Task for Integrated Project combining Chemical Engineering Thermodynamics I and Process Heat Transfer subjects

Besides, an adjunct lecture with a principal engineer from Malakoff Power HQ was conducted, as shown in Figure 3. The talk on a gas turbine system was advantageous to the students as the gas turbine system is one of the examples of cycle used in power plant. This sharing session provided the students with clearer view on how a real power plant operates and gave ideas on designing the process as instructed in the integrated project.

At the end of the session, the engineer managed to provide feedback, as follows:

> "Good program for the students to be exposed to the industrial application on the knowledge gained from the university. It is also a good platform for me to give back for the good of future generations. Doing this through a virtual platform, travelling can be eliminated, but it is somewhat difficult to gauge the level of the presentation (too advanced, too detailed and not easily understood?) among the students; something that probably the university lecturer can follow through and give feedback or enquiry to me. I would also be grateful for any feedback on my session (contents, explanation, etc.) so that we can further improve in the future session."

At the end of the semester, after submitting the project report, students were required to write and submit peer rating and reflections on their experience with the integrated project. Online medium such as Microsoft Form was used for the students to post their reflections. Microsoft Word softcopy of peer rating was used for students to submit the peer rating. As for the peer rating, each student was required to evaluate their team members. The evaluation form is shown in Figure 4.

Meanwhile, for the reflections, three questions were asked to the students as follows.

1. How did you feel, and what did you think of the project?
2. Did the experience from the project achieve any of your learning goals?
3. From the project, did you realize that two different subjects are related to each other?

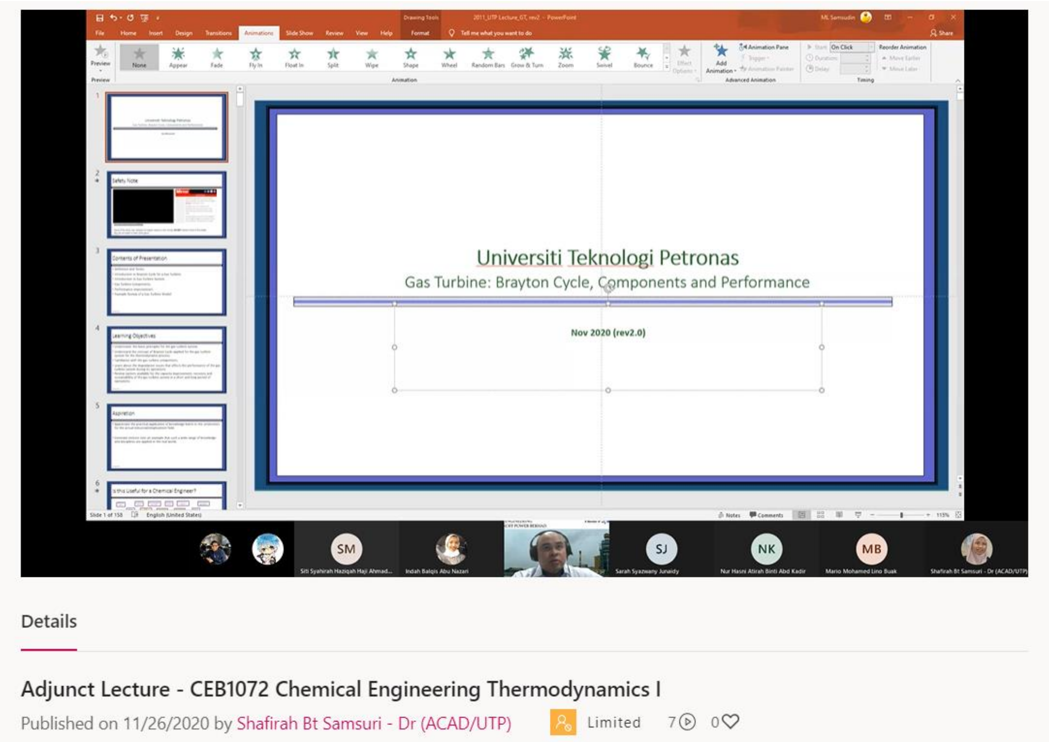


Figure 3. Sharing session from Mr Mohamad Lutfi Samsudin, Malakoff Power HQ

Confidential: *To be completed by student and submitted to lecturer individually*

Name:

Student ID:

Name of Team Member	ID	Evaluation Maximum marks 10 for each criteria					Overall evaluation (a+b+c+d+e)/5
		(a)	(b)	(c)	(d)	(e)	
1.							
2.							
3.							
4.							

Criteria: (a) Attending the group meetings
(b) Teamwork and cooperation
(c) Knowledge input to project
(d) Timely and correct completion of project
(e) Contribution to successful completion of project

Assessment scheme:

Average Score	Factor	Scale
7 - 10	1.0	Above expectation
4 - 6	0.5	Meet expectation
1 - 3	0	Below expectation

Signature:

Figure 4. Peer evaluation form

Discussion

The learning experience gained by the students can be translated based on the reflection done by ten students (out of 11 students) involved in this integrated project, as shown in Figures 5 (Table 2) and 6 (Table 3).

Summary of Reflection from Lecturers

The integrated project was done in September 2020 semester. During this time, the teaching and learning were done in online mode due to pandemic COVID-19. Concerning the burden of students doing many projects for many subjects in one semester caused the lecturers to discuss and agreed to combine projects from two subjects into one integrated project. Besides, the correlation between two subjects in solving one project can be seen from this integration.

The lecturers were delighted once the students successfully completed the project with their guidance. This was also the output from multiple discussions between students and their respective lecturers. The sharing session (adjunct lecture) by the principal engineer from Malakoff Power HQ triggered students to be more motivated to complete the project. The cycle that involved and the actual equipment utilized in the plant were shown during the session. As the problem statement of the project was related to the existing plant, the students gained a lot of ideas and could relate with the project they solved. The lecturers were satisfied and motivated to pursue and improve the integrated project for future semester.

Summary of Reflection from Students

Figure 5 summarises the difficulty of this integrated project, and about 50% of students mentioned that this integrated project is demanding and challenging. Table 2 showed that five students (out of 10 students) agreed that this integrated project is demanding and challenging. It was found that most of them responded similarly to the first question (refer to methodology section).

- "To be honest, it is a challenging project that requires deep understanding and outside knowledge to complete this project."
- "Not too bad, but the project is at a high level."

Meanwhile, about 30% agreed that even though this integrated project is complex, they managed to relate the project with both subjects: Chemical Engineering Thermodynamics I and Process Heat Transfer. A total of 3 students (out of 10 students) mentioned that they managed to relate both subjects involved in this integrated project, even though the project was complex. On the other hand, 20% of them (2 out of 10 students) stated that the integrated project is challenging. Still, they can complete the integrated project with the help and guidance from both lecturers.

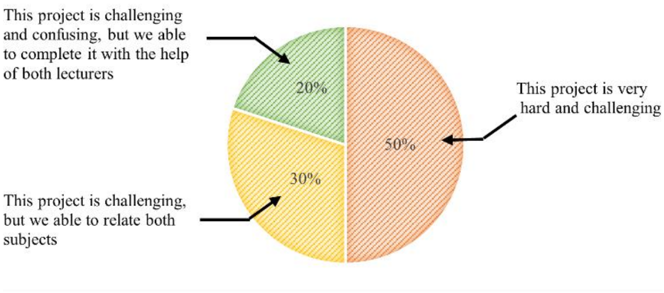


Figure 5. Reflection results on this integrated project level of difficulty (first question)

Table 2. Student's response to the first question

Student's respond	Number of students
This project is very hard and challenging	5
This project is challenging, but we able to relate both subjects	3
This project is challenging and confusing, but we able to complete it with the help of both lecturers	2
Total number of student	10

On the other hand, for the second question, 70% of students (7 out of 10 students) agreed that this integrated project gave them a clear view of the industrial application, especially on the heat exchanger application. Meanwhile, 20% of them (2 out of 10 students) stated that the integrated project enhanced their understanding of both subjects and helped them relate both subjects in one application. Only 10% of them (1 out of 10 students) mentioned that their learning goal is not achievable. However, they still managed to solve the problem. The summarized reflection results on the second question are illustrated in Figure 6 and Table 3.

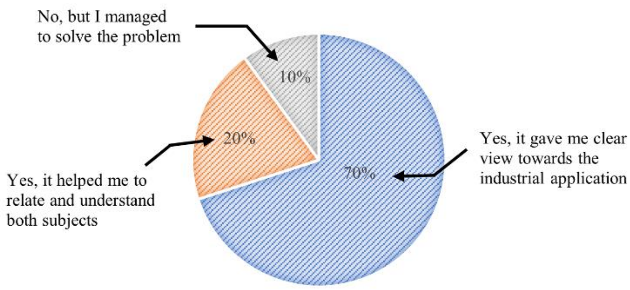


Figure 6. Reflection results on students' learning goal achievable through this integrated project

Table 3. Student's response to the second question

Student's respond	Number of students
Agree that this integrated project gave a clear view of the industrial application	7
Agree that this integrated project helps them to relate and understand both subjects involved	2
Disagreed that this integrated project goal is achievable. However, he/she managed to solve the problem	1
Total number of student	10

For the third question, based on the reflection analysis, 90% of the students (9 out of 10 students) achieve this integrated project's objectives which were to relate two different subjects when learning in the same semester and to help them apply those two different subjects on the same application. By comparing the outcome of this integrated project with the conventional learning approach, which is via lecture, the integrated project can improve the students' knowledge and skill. Besides, the integrated project is expected to increase the students' participation in solving the problems. It allows students to work in a group, increasing their motivation, time management, multi-tasking, and leadership skills.

The findings from this study were aligned with the statement made by Azizan et al. (2018), where project-based learning was introduced to replace the traditional learning approaches (lectures). Moreover, Moon (2007) mentioned a learning approach where students can relate to real-life situations far better than the lectures. Many studies agreed that lectures as learning approaches were ineffective as students could not strengthen their scientific knowledge and professional skills (Aziz et al., 2013; Lukman et al., 2013; Mamat & Mokhtar, 2008). Both scientific knowledge and professional skills are the essential requirements for students to become engineers who have high capability in engineering practice and can be recognized as great leaders (Megat Mohd Noor et al., 2002).

Conclusions

In conclusion, the new learning approach with the concept of project-based learning has proven to improve students' thinking and problem-solving skills. Besides, this integrated project increases the students' participation as they need to work in a group to solve the problem. In this study, the Integrated Project introduced is Heat Recovery from Ammonia Synthesis Reactor for Power Generation, covering two core subjects in First Year First Semester of Chemical Engineering studies (Chemical Engineering Thermodynamics I and Process Heat Transfer). The students' reflection analysis showed that this integrated project achieved the objectives of this study. Most students could relate to two different subjects when learning in the same semester and apply those two different subjects on the same application. Even though 50% of the students (5 out of 10 students) agreed that the integrated project is complicated and challenging, 70% of them (7 out of 10 students) mentioned that this integrated project gave them a clear view of the industrial application, especially on heat exchanger application. These results supported the claim that the new learning approach via project-based learning helps students improve their skills and enhance their understanding of the subjects.

Acknowledgement

The authors would like to express their appreciation to the Chemical Engineering Department, Universiti Teknologi PETRONAS, for the support. The authors also would like to thank students who had participated in this study.

References

Aziz, A. A., Yusof, K. M., Sadikin, A. N., Udin, A., Yatim, J. M., & Hezmi, M. A. (2017). Effective use of Problems in Learning Environments for Attaining Environmental Sustainability Outcomes. 2017 7th World Engineering Education Forum (WEEF), 648–653. https://doi.org/10.1109/WEEF.2017.8467062

Aziz, A. A., Yusof, K. M., Udin, A., & Yatim, J. M. (2013). Development of Students' Knowledge-behavioural Changes in Relation to Sustainability through a Case Study. Procedia - Social and Behavioral Sciences, 102, 568–576. https://doi.org/10.1016/j.sbspro.2013.10.773

Azizan, M. T., Mellon, N., Ramli, R. M., & Yusup, S. (2018). Improving teamwork skills and enhancing deep learning via development of board game using cooperative learning method in Reaction Engineering course. Education for Chemical Engineers, 22, 1–13. https://doi.org/10.1016/j.ece.2017.10.002

Biggs, J. (2003). Aligning teaching and assessing to course objectives. 10.

Dewey, J. (1916). Democracy and Education: An Introduction to the Philosophy of Education. Macmillan.

Glaser, R., & Resnick, L. B. (2016). Knowing, learning, and instruction: Essays in honor of Robert Glaser. http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=1920289

Helmi, S. A., Mohd-Yusof, K., & Zakaria, Z. Y. (2020). Guideline to an Effective Implementation of Student-Centered Learning in Engineering Education: Informal Cooperative Learning (ICL). 7.

Jumaat, N. F., Tasir, Z., Halim, N. D. A., & Ashari, Z. M. (2017). Project-Based Learning from Constructivism Point of View. Advanced Science Letters, 23(8), 7904–7906. https://doi.org/10.1166/asl.2017.9605

Kelly, N. (2014). Teaching Science in Elementary and Middle School: A Project-Based Approach. Interdisciplinary Journal of Problem-Based Learning, 8(1). https://doi.org/10.7771/1541-5015.1489

Lukman, R., Lozano, R., Vamberger, T., & Krajnc, M. (2013). Addressing the attitudinal gap towards improving the environment: A case study from a primary school in

Slovenia. Journal of Cleaner Production, 48, 93–100. https://doi.org/10.1016/j.jclepro.2011.08.005

Mamat, M., & Mokhtar, F. (2008). Effective instructional design for value dominant education in Malaysian public universities. Social and Management Research Journal, 5, 61. https://doi.org/10.24191/smrj.v5i2.5160

Megat Mohd Noor, M. J., Ali, A., Osman, M., Sapuan, S., Mariun, N., Jaafar, M., Ghazali, A., Omar, H., & Yusuff, R. (2002). A new engineering education model for Malaysia. International Journal of Engineering Education, 18, 2002.

Moon, J. (2007). Critical Thinking: An Exploration of Theory and Practice. Routledge.

Nielsen, S. H. (2003). The Aalborg Experiment University Industry Interaction: A Means For Stimulating Engineering Excellence In Technology And Learning Systems. 2003 Annual Conference Proceedings, 8.1098.1-8.1098.12. https://doi.org/10.18260/1-2--11789

Reaburn, P., Muldoon, N., & Bookallil, C. (2009). Blended spaces, work based learning and constructive alignment: Impacts on student engagement. Proceedings of the 26th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education, ASCILITE 2009, 820–831. https://research.bond.edu.au/en/publications/blended-spaces-work-based-learning-and-constructive-alignment-imp

Tyler, R. W. (1989). Basic principles of curriculum and instruction. Univ. of Chicago Press.

Yam, L. H. S., & Peter, R. (2010). Implementing a Project-Based Learning Approach in an Introductory Property Course. 19.

Tatar, E. & Oktay, M. (2011). The effectiveness of problem-based learning on teaching the first law of thermodynamics. Research in Science & Technological Education, 29, 3. https://doi.org/10.1080/02635143.2011.599318

Literature Review on the Factors Affecting Teaching Effectiveness of Undergraduate Engineering Programmes

Article history
Received
12 September 2021
Received in revised form
16 August 2021
Accepted
20 August 2021
Published online
30 November 2021

Sahudin, S.[a], Maideen, N.C.[b], Shamsudin, A.F.[a], Shuib, N.A.[c]
[a] Quest International University, Ipoh, Perak, Malaysia.
[b] Universiti Teknologi MARA, Permatang Pauh, Pulau Pinang, Malaysia.
[c] University Malaysia Perlis, Kangar, Perlis, Malaysia.
** shuibbs@gmail.com*

Abstract
A great deal has been written, over the past three decades, on what constitutes effective teaching in higher education. Teaching effectiveness has been a key concern for universities since it pertains to the achievements of skills required for the competitive job market. The current practice of teaching the engineering fundamental non-culminating courses in undergraduate engineering programmes is through traditional teaching methods. This literature review aims to identify the factors that influence teaching effectiveness of undergraduate engineering programmes. The literature reviewed indicates that researchers have identified lecturers' ability, course characteristics and teaching methods & material as pertinent measurements of Teaching Effectiveness.

Keywords: Teaching effectiveness, lecturers' ability, course characteristics and teaching methods & materials.

Introduction

Teaching effectiveness (TE) is a less researched topic in developing countries like Malaysia. It is found, through personal teaching experiences, that final year engineering students lack understanding in integrated design project (IDP) course. Basically, this course is the combination of previous courses. Therefore, if engineering students don't have a strong command on the courses of earlier semesters, it would not be possible for them to understand this IDP course. On the other hand this IDP course is the most important subject for engineering graduates to demonstrate their skills in the job work place. It is a matter of great concern that engineering students lack understanding of this course and it indicates that the problems in previous courses distorted the teaching outcome. Therefore it is necessary to identify the factors that influence the TE of engineering courses. This TE is supposed to influence the employability of our graduates. This situation motivated us, as lecturers who experience this personally, to conduct this study.

Traditionally, teaching means imparting knowledge or skill. It is used interchangeably with pedagogy (Diamond, 2013). A great deal has been written, over the past three decades, on what constitutes effective teaching in higher education (Duarte, 2013). There is some evidence that an understanding of what constitutes effective pedagogy – the method and practice of teaching – may not be so widely shared, and even where it is widely shared it may not actually be right (Hamre et al., 2009; Strong et al., 2011). Hence, it is necessary to clarify what is effective pedagogy. What are the significant factors of TE in undergraduate engineering programmes? This literature review explores the factors affecting TE in undergraduate engineering programmes.

The current practice of teaching the engineering fundamental non-culminating courses in undergraduate engineering programmes is through traditional teaching methods. According to Kıymet Selvi (2012), while the creation and construction of knowledge must be the main issues in the learning-teaching process, creating and constructing knowledge cannot be the primary aims for them in the typical formal learning-teaching system. Students and teachers don't have sufficient time to create and construct knowledge in the formal learning-teaching process, so teachers mostly transmit and distribute ready-made knowledge in this process. In the formal learning-teaching system, students must follow their teachers' plans and other education policy-makers who decide what type of knowledge and experiences are important for students' learning. Engineering programmes are a coherent set of taught elements, courses or modules which leads to a qualification such as a degree. Programmes which lead to a first degree such as BEng, BSc or BS are called undergraduate programmes (Goodhew, 2010).

A proper understanding of TE is a vital factor for any educational institution. From this study, engineering lecturers can ascertain where the attention needs to be given for planning and implementing the right knowledge and teaching practices. Academicians can impart the knowledge content and skills generated from this review among the learners who might materialize it in their practical field. A great concern regarding the issue of TE is the specific constructs that influences TE. The findings of this review will add new dimensions in the literature relating to TE.

Sahudin, S, Maideen, N.C., Shamsudin, A.F., Shuib, N.A. (2021), Literature Review on the Factors Affecting Teaching Effectiveness of Undergraduate Engineering Programmes, *ASEAN Journal of Engineering Education*, 5(1), 17-24.

Literature Review

For many years, teaching effectiveness (TE) at higher education institutions has been the focus of many researchers (Cohen, 1981; Lewis et al., 1988; Mukherji & Rustagi, 2008). Traditionally, teaching means imparting knowledge or skill. Effective means efficient or successfully producing desired result or outcome. In order to determine the determinant factors affecting TE, one must first arrive at a comprehensive definition of teaching effectiveness. TE encompasses imparting relevant knowledge & skills efficiently or successfully to the point where students have mastered the subject or courses taught (Van der Marwe, 2012). TE also judges whether studies provide credible evidence of positive student outcomes (including knowledge, skills, attitudes, and values) linked to particular practices. In addition to examining student achievement, other factors such as student motivation, interest in subject matter and career aspirations can be impacted by teaching (Stark-Wroblewski et al., 2007).

For the teaching characteristics of engineering colleges, TE is connoted as follow: effective teaching is teaching activities the teacher applies, at the optimal speed, effectively and efficiently to encourage or allow the students to achieve "three dimensions objectives", encompassing (i) knowledge and skills, (ii) process and methods, and (iii) attitudes and values. All while sustaining progress and development in order for the student to meet the education standards of the society and the students' own personal needs. Several past studies found that students' evaluation of teaching effectiveness (SET) offers a reliable and valid assessment of teaching (Hooper & Page, 1986; American Accounting Association, 1988; Cranton & Smith, 1990; Holtfreter, 1991; Toby, 1993). In fact, SET is one of the most commonly used teaching evaluation methods in universities worldwide (Newton, 1988; Seldin, 1989; Stratton, 1990).

TE can be measured by how much students learn within a given class. The student learning method is used infrequently. Despite the limitations and difficulty inherent in the measurement of student learning, some researchers have found that this method is reliable and valid. Student evaluations of teaching instruction are the most commonly used and easiest to assess in university settings, despite opposition from instructors who argue that students' ratings are popularity contests (Al-Issa & Sulieman, 2015). Overall, student ratings appeared to be a reliable and valid measure of TE (Kogan & Schoenfeld-Tacher, 2010).

Determinant Factors Affecting TE

Although student evaluations have become the primary tool used to evaluate the TE of their faculty (Seldin, 1993), Simpson (1995) found that student evaluations were the most consistent and most controversial source of information used to evaluate TE. Despite some dissent among higher education professionals, a large body of research evidence indicates that student evaluation of teaching is valid. This opinion is partly based on evidence from the research showing a positive correlation between student evaluations of faculty members and objective measures of student achievements (Yunker & Yunker, 2003).

Green et al. (1999) found that students are able to reliably evaluate effectiveness of teaching and that student evaluations are a valid tool for measuring teaching ability. Cohen (1981) also suggests that student evaluations are generally valid and reliable and serve as good predictors of how much students actually learn in class and consequently are used as a primary information source in evaluating TE (Green et al., 1998). Amin (2002) is of the opinion that the results of student evaluations may help the lecturers to improve upon their teaching strategies; it may help students in the choice of their courses and it could be useful to administrators in their decisions concerning promotion appointments and renewal of lecturing contracts.

Frey (1973, 1974, and 1978) and others have strongly argued for including only the individual teaching dimensions to the exclusion of global rating attributes which he demonstrated in a measure developed by him which he called as "Endeavor." Marsh and Dunkin (1992) take a middle path between the positions adopted by Abrami et al. (1997), wherein they recommend using attributes of both individual teaching dimensions and global ratings. Ryan and Harrison (1995) recommend that three types of student rating information should be used in making personnel decisions: individual teaching dimension ratings; overall evaluations made by students; and a composite weighted average indicating an overall evaluation score. Burdsal and Harrison (2008) in their study provide empirical evidence supporting the use of both multidimensional scale and an overall evaluation for determining TE, as valid indicators of student perceptions of effective classroom instruction. According to Shevlin et al. (2000) students may be systematically influenced by teachers' traits (such as "charisma") and give higher ratings to their teachers irrespective of their actual TE. They cite theories of personality (Asch, 1946; Bruner et al., 1958) and research evidence, which shows that manipulation of bipolar attributes such as warm-cold (Kelley, 1950) significantly impact students' judgment of their teachers. So, student perceptions of a single attribute may influence judgments' of the individual teacher across various dimensions (Vernon, 1964).

There is ambiguity on whether the determinant variables being measured are dominant because they are measurable. It is also unclear how much the dimensions of Student Evaluation of Teaching Effectiveness (SET) can influence TE construct (Abrami et al., 1997; Marsh & Roche, 1997).

Hamid and Pihie (2004) stated that service quality factors in teaching comprised five (5) measures: (i) Lecturer factor, (ii) Teaching methodology, (iii) Course relevance, (iv) Facilities, and (v) Support services. However, Hamid and Pihie (2004) conducted analysis on the quality of teaching using only the measures for Lecturer factor, Teaching methodology, and Course relevance because these three were the only dominant factors assumed to be directly under the control or influence of the Faculty and lecturers.

Lecturer's Ability

Lecturer's Ability refers to the capability of the instructors to teach effectively so that the best teaching outcome is achieved. It is often used interchangeably with Teaching Ability. Educators believe that the act of teaching creates an intimate and inseparable relationship between teacher and student (Ovando, 1989). This symbiotic relationship must be considered an important element in the process of evaluating and improving instruction in higher education, especially since the ultimate result of effectiveness of teaching is student learning and their mastering of the content of specific courses. Therefore, students' feedback and perceptions of teaching should play a role in improving the quality of education (Van der Marwe, 2012; Mart, 2017; Serin, 2019). Evaluating a faculty member's teaching ability is one of the most difficult and contentious tasks faced by administrators. Although teaching ability is regarded one of the primary factors in promotion and tenure decisions, there is little agreement on how TE should be measured (Lewis et al., 1988; Mukherji & Rustagi, 2008).

At the heart of TE is the teacher's ability to understand the individual profiles (i.e. the strengths and weaknesses) of every student in the classroom. Based on these factors, teachers can then adjust the instructional intensity necessary in order to meet the academic goals (Elizabeth, 2013). For those students working at or above grade-level, the teacher can extend the academic goals to encourage students to reach higher levels of achievement. Most importantly, the teacher can set his or her instructional priorities and manage available time and resources to help the students who are in greatest need. The teacher provides whole-group instruction on the particular concept, and then gives students the opportunity to practice that particular skill or concept through peer discussions, independent center activities or homework assignments. Graded homework assignments and subsequent curriculum based tests (such as an end-of-unit quiz) helps the teacher understand which students may be struggling and require further instruction (Elizabeth, 2013). So, lecturers' ability is very important for teaching effectiveness.

Traditionally, lecturers are evaluated according to three major criteria: teaching, research, and services. While research and services are evaluated by departmental and university committees, TE is evaluated by the students. Student evaluations are the primary tool used by administrators to evaluate TE (Yunker & Sterner, 1988; Mart, 2017; Serin, 2019). Teaching is multidimensional in nature and there are many possible indicators of effectiveness of teaching. The procedures for developing and using student evaluation instruments have varied considerably. Faculties often argue that TE is difficult to identify and nearly impossible to validly measure, so individual faculty members should be allowed to use subjective judgment to determine how to conduct their classes (Simpson, 1995). However, since TE is one of the primary factors used in promotions and tenure decisions, faculty members and administrators need to agree on a valid method to evaluate teaching ability.

Wei Hong and Shen Jiliang (2002) required students to evaluate the teaching of the teachers according to the teaching evaluation table. The results through their empirical study show that (the teacher's characteristics in effective teaching) the students' ability improved by the teacher's teaching, clear expression by the teacher, distinctive teaching style and characteristic of the teacher, teachers responsible for teaching and difficult contents prominently, and the teachers ability to stimulate the students' interest and initiative.

Mixed results were reported on the association between student evaluation results and course level or division (Liaw & Goh, 2003; Green et al., 1998). Instructors teaching at higher levels often received better student evaluation ratings, presumably because higher level students, while being more motivated in their studies, are also more discriminating in their evaluations (Langbein, 1994; Holtfreter, 1991; Aleamoni & Hexner, 1980; Cashin, 1989; Shapiro, 1991). Others have shown that instructors of different levels of courses received relatively different ratings (Cranton & Smith, 1986; Koh & Tan, 1997). Most research reports no differences between faculty evaluations given by students in graduate and undergraduate courses (Gage, 1961; Goldberg & Callahan, 1991). However, some studies (i.e. Boex, 2000; Whitworth et al., 2002) noticed that graduate students did evaluate faculty members more favorably than undergraduate students. Mulford and Schneider (1988) found no significant differences between the mean ratings of instructors teaching undergraduate and graduate courses.

Smith (1995) stated that in education, teachers are the main resource of creating high-quality opportunities for the students. Sometimes teachers do good things and do bad things. Teachers should have the understanding of what they are to do and are ready to share all this will have an effect on students. According to Bates (2012), great communication between students and teachers are the building blocks of the best educational relationship that a teacher and student should have. The good instructors are noted by how they explain information to their students. How well they provide feedback to allow ideas to be expressed freely and actively ask questions between learner and educator. And with the advent of the latest technology in education, teachers can promote themselves as modern educators. They can connect positively to students every time and at varied ways. According to Ihmeidah et al. (2010), teachers are collecting, sorting, analyzing and explaining information to students. Teachers should have good communication skills to be successful in their jobs. Teachers need listening, interpersonal, written and oral communication skills to facilitate teaching. The outcome of the attitudes toward communication skills can make both teachers and their students be more prepared for their classroom environment and improving effective communication.

Ismail et al. (2018) breaks down Lecturer's ability into seven aspects: organization, speech-pacing, clarity, enthusiasm, interaction, rapport, and disclosure. It was found that the most highly rated aspects were organization and speech-pacing.

Robert Coe et al. (2014) suggest that teachers should consider Pedagogical Content Knowledge when assessing teaching quality, as strong evidence shows that focusing on these components can improve student outcomes. The very best teachers are those that demonstrate pedagogical content knowledge. The most effective teachers have deep knowledge of the subjects they teach, and when teachers' knowledge falls below a certain level it is a significant impediment to students' learning. As well as a strong understanding of the material being taught, teachers must also understand the ways students think about the content, be able to evaluate the thinking behind students' own methods, and identify students' common misconceptions. Dardiri (2017) found that there was no correlation between work environment and teacher performance, meaning that the work environment (conditions of physical work environment, psychological work environment, and non-physical work environment) does not positively support the pedagogical and professional performance of teachers.

In summary, the literature reviewed indicates that lecturer's ability is a valid measure of TE. Therefore, whether the Lecturers' ability influences TE or not, should be investigated further.

Course Characteristics

The course content, service given by the lecturers and the faculty, course assessment, instruction medium, social activities, concern for students and facilities constitute the course characteristics of a programme (Peng & Samah, 2006). The course characteristics are related to academic program given to students (Le Blanc & Nguyen, 1997; Kwek et al., 2010). Considerable evidence exists that the subject matter of a course affects students' evaluation of teaching effectiveness (SET) (Neumann & Neumann, 1983; DeBerg & Wilson, 1990; Cho & Baek, 2019). Some authors suggested that the nature of the subject might explain the variation in SET results (Clark, 1993; DeBerg & Wilson, 1990; Cranton & Smith, 1986; Langbein, 1994).

The assessment dimension of teaching is related to the standards and academic assessment system applied by the university (Peng & Samah, 2006). Academic score for formal educational institutions is an outcome indicator of the success of an educational program (Sang, 2007). Achievement of a university student is generally measured by his or her academic score or grade point average (GPA). Research by Lagrosen et al. (2004) shows that internal evaluation, including course evaluation, is one of student perceived service quality which denotes the teaching outcome. Hence the course characteristics are being used as a standard measure for teaching effectiveness. Lizzio et al. (2002), proposed good teaching, clear goals and standards, appropriate workload, appropriate assessment, emphasis on independence and generic skills, and an overall satisfaction item that can be used as a simple means for the criterion-related validity checking of these scales.

The course characteristics should clearly portrait learning objectives, assessment and instructional strategies (Fink, 2003). There should have a clear guideline of what course structure should be; finding strategy of teaching to approach learning goals and setting schedule. The course characteristics also imply the syllabus which is a guideline and summary topics of the course study. A syllabus shows information about the course schedule, test dates, due dates for assignment, the policy for grading of the subject, specific classroom rules and etc. As in many courses it concludes in the exam. From syllabuses it is guaranteed that all teachers should have the knowledge of what must be taught and what are not to be taught. Test papers can only measure knowledge based on what is learned that are in the syllabus. Good syllabus should show what students will do and learn, and what they can expect. It guides student learning with the expectations and decreases the number of problems in the course. According to Patricia (2008) the course characteristics have a positive effect on teaching outcome as it is a written agreement, even if it is not in the legally recognized. It shows expectations about the course and tasks early in the semester.

In many articles, curriculum is also known as course content (Kwek et al., 2010; Peng & Samah, 2006; Mart, 2017), subject content (Athiyaman, 1997), program issues (Ford et al., 1999), and academic concerns (Russel, 2005). Several articles show that curriculum is overall student perceived outcome determinant (Athiyaman, 1997; Sohail & Shaikh, 2004). Other research shows that curriculum has a positive relationship with overall student perceived quality or teaching outcome (Le Blanc & Nguyen, 1997; Kwek et al., 2010). Previous literature indicates that curriculum has a positive influence on overall student perceived service quality, and was referred to as a student perceived service quality determinant (Athiyaman, 1997; Sohail & Shaikh, 2004). The assessment system also has a positive significant effect on overall teaching outcome. This means that any improvement in the assessment dimension will result in improved perceived service quality. Thus, the assessment system is also an important issue for making teaching effective and its importance is increasing.

In summary, the literature reviewed indicates that course characteristics is a valid measure of TE. Therefore, whether the course characteristics influences TE effectiveness or not, should be investigated further.

Teaching Methods & Materials

The teaching methods & materials (TM) are related to the way of imparting knowledge and physical facilities that support both academic and non-academic activities (Joseph et al., 2005; Peng & Samah, 2006; Kwek et al., 2010; Ko et al., 2014). In several articles, this dimension is also referred as tangibles (Soutar & McNeil, 1996; Cuthbert, 1996; Pariseau & McDaniel, 1997; Ham & Hayduk, 2003; Abu Hasan et al., 2008), physical evidence (Sohail & Shaikh, 2004), and physical aspects (Ford et al., 1999). Some other researchers alter these dimensions to some specific dimensions, such as computing facilities (Hill, 1995; Athiyaman, 1997) and recreational facilities (Athiyaman, 1997). A study by Joseph et al. (2005) surveyed 450 students of a small liberal arts university in the US shows that facilities – by using Importance-Performance analysis methods – are located in "concentrate here" quadrant. The literature shows that facilities are considered important from a student's perspective. Le Blanc & Nguyen (1997) stated that teaching methods & materials have a positive and significant impact on overall student perceived quality.

Universities all over the world are using teaching methods & materials (TM) as ways to increase teaching outcome. Their teaching methods & material include both academic and extra curriculum activities that include teaching and student involvement in curriculum; joint consultation; work expertise placements, computing facilities, library service, university bookshop, careers service; counseling welfare; financial service; health service; accommodation services, students' union; catering service; physical education and travel agency (Hill, 1995). Athiyaman (1997) also mentioned that teaching capability, staff availability, library service, computing facilities; class sizes, subject content, student workload and recreational facilities might bring forth better teaching outcome of university graduates. On the other hand, Lagrosen et al. (2004) stated that teaching outcome can be increased by corporate collaboration, information and analysis, courses offered, internal evaluations, computer facilities, collaboration and comparisons and finally library resources.

The medium of instruction dimension related to teaching, learning and assignment activities is also an important factor for making teaching effective (Peng & Samah, 2006). The instruction medium has a positive significant effect on perceived service quality of graduates. The instruction medium dimension is related to the use of language in academic activities. This dimension is important because students generally hope to work in a multinational company, where English is a prerequisite. In a developing countries context, the capability of speaking English for the student provides added value, as it is not their native language. Russell (2005) argued that teaching and learning activities using English is a factor considered by the student in choosing a university. Furthermore, Peng & Samah (2006) also found that the instruction medium dimension is a student perceived quality determinant and significantly influences teaching outcome. Therefore universities should provide sufficient academic and non-academic supports to increase the teaching outcome.

Research suggest that teachers should consider quality of instruction when assessing teaching quality, as strong evidence shows that focusing on this components can improve student outcomes (Robert Coe et al., 2014; Cho & Baek, 2019). The very best teachers are those that demonstrate quality of instruction which includes elements such as effective questioning and use of assessment by teachers. Specific practices, like reviewing previous learning, providing model responses for students, giving adequate time for practice to embed skills securely and progressively introducing new learning (scaffolding) are also elements of high quality instruction.

In summary, the literature review indicates that teaching methods & material is a valid measure of TE. Therefore, whether the teaching methods & material influences TE effectiveness or not, should be investigated further.

As an overall summary, the literature review indicated that researchers have identified lecturers' ability (Yunker & Yunker, 2003; Wei Hong & Shen, 2009; Bates, 2012; Elizabeth, 2013), course characteristics (Athiyaman, 1997; Le Blanc & Nguyen, 1997; Sohail & Shaikh, 2004; Kwek et al., 2010) and teaching methods & material (Lizzio et al., 2002; Sang, 2007) as pertinent measurements of Teaching Effectiveness.

Discussion and Conclusion

Universities should design the courses or programs in a way so that students can achieve the required skills necessary for the competitive job market. For this reason TE has become a key issue for the educational institutions. Through extensive literature review lecturers' ability, teaching methods & materials and course characteristics were found to be determinants of TE. Future studies could be recommended to determine which among the determinants are the most important factors.

Lecturers are the ones who might exhort great influence on their students. This is due to the fact that lecturers have direct contact with the students. Literature reviewed indicates that lecturers' ability is a significant factor that ensures TE. If the lecturers have strong command on their subject knowledge and they are good enough to make things clear to the students, it would surely yield better teaching outcome which is the expectation of both graduates and employers. Better teaching outcome also increases the chances of graduates' employability. Therefore, universities should emphasize on the lecturers' ability to ensure teaching effectiveness.

Course characteristics obviously influence the learning process of the university students. The course content, service given by the lecturers and the faculty, course assessment, instruction medium, concern for students and facilities constitute the course characteristics of the program (Peng & Samah, 2006). Educational researchers think that course characteristics are important issues to the success of any teaching programs (Lagrosen et al., 2004). The literature reviewed indicates that course characteristics are significantly related to teaching effectiveness. It implies that TE can be gained by providing the students a clear guideline of course structures, specific strategies of teaching to achieve learning goals and setting proper schedule. From the beginning of the courses, students should be given the syllabus which is a guideline of information about the course schedule, test dates, due dates for assignment, the policy for grading of the subject, specific classroom rules and etc. If they get this earlier in the semester, it will help them to make plans for the whole academic semester. This clear guideline regarding the courses might help the students to grasp the comprehensive knowledge of a particular subject. Hence universities should put forth efforts to develop an effective course curriculum and provide it to the students so that the best teaching outcome can be achieved.

Teaching methods & materials also play an important role in imparting knowledge to university students. The process of teaching and physical facilities that support both academic and non-academic activities are expected to generate positive effect on teaching outcome (Joseph et al., 2005; Peng & Samah, 2006; Kwek et al., 2010). The literature reveals that teaching methods & materials are correlated to teaching effectiveness. This calls for the enhancement of academic and non-academic facilities like physical evidence, computing facilities, joint consultation, work expertise placements, library service, university bookshop, careers service, counseling welfare, financial service, health service, accommodation services, students' union; catering service, physical education staff availability, class sizes, and recreational facilities which might bring forth better teaching outcome of university graduates.

In summary, the literature reviewed indicates that researchers have identified lecturers' ability (Yunker & Yunker, 2003; Wei Hong & Shen, 2009; Bates, 2012; Elizabeth, 2013), course characteristics (Athiyaman, 1997; Le Blanc & Nguyen, 1997; Sohail & Shaikh, 2004; Kwek et al., 2010; Cho & Baek, 2019) and teaching methods & material (Lizzio et al., 2002; Sang, 2007; Cho & Baek, 2019) as pertinent measurements of TE.

Future study could be recommended to add new knowledge in the body of literature regarding determinants of TE and graduates employability. There is a debate in literature about the generalizability of the structure and the validity of the measures of student evaluation of teaching effectiveness (SET). A great concern regarding the issue of TE is the specific constructs that influences TE. Future study could be recommended to address this issue by investigating the influence of lecturers' ability, course characteristics and teaching methods & materials on TE. Findings of future study could add new dimensions in the literature relating to TE. Future study findings could determine whether lecturers' ability, course characteristics and teaching methods & materials are strong predictors of TE.

Previously researchers only focused on developing and validating the measures of TE; but issues relating to the specific constructs that might influence TE still remained unaddressed. There is still lack of consensus about the number of dimensions that constitute TE and to what extent TE is influenced by the existing factors (Abrami et al., 1997; Marsh & Roche, 1997). Future study could provide strong support for all these gaps by exploring the significant predictors of TE.

References

Abrami, P.C., D'Apollonia, S. & Rosenfield, S. (1997). The dimensionality of student ratings of instruction: what we know and what we do not, in Perry, R.P. and Smart, J.C. (Eds), Effective Teaching in Higher Education: Research and Practice, Agathon Press, New York, NY, pp. 321-367.

Abu Hasan, H.F.A., Ilias, A. & Rahman, R.A. (2008). Service quality and student satisfaction: a case study at private higher education institutions, International Business Research, 1 (3), pp. 163-75.

Al-Issa, Ahmad & Sulieman, Hana (2015) Student Evaluations of Teaching: Perceptions and Biasing Factors. Quality Assurance in Education 15 (3), pp. 302-317

Aleamoni, L. & Hexner, P. (1980). A review of the research on student evaluation and a report of the effect of different sets of instructions on student course and instructor evaluation, Instructional Science, Vol. 9, pp. 67-84.

American Accounting Association (1988). A Framework for the Development of Accounting Education Research, American Accounting Association, Sarasota, FL.

Amin, T.G. (2002). A functional linguistic approach to concepts and concept learning in science. Doctoral Dissertation, Department of Psychology, Clark University, Worcester, MA, USA.

Asch, S.E. (1946). Forming impressions of personality, Journal of Abnormal and Social Psychology, 41 (2), pp. 258-290.

Athiyaman, A. (1997). Linking student satisfaction and service quality perceptions: the case of university education, European Journal of Marketing, 31 (7), pp. 528-40.

Bates, L. (2012). Ten Great Tools for Student-Teacher Communication.

Boex, L. (2000). Attributes of effective economics instructors: an analysis of student evaluations, Journal of Economic Education, Summer, pp. 211-27.

Bruner, J. S., Shapiro, D. & Tagiuri, R. (1958). The meaning of traits in isolation and combination. In R. Tagiuri & L. Petrullo (Eds.), Person perception and interpersonal behavior (pp. 277-288). Stanford, CA: Stanford University Press.

Burdsal, C.A. & Harrison, P.D. (2008). Further evidence supporting the validity of both a multidimensional profile and an overall evaluation of teaching effectiveness,

Assessment and Evaluation in Higher Education, 33 (5), pp. 567-576.
Cashin, W.E. (1989). Defining and evaluating college teaching, Paper No. 21, IDEA, Kansas State University Center for Faculty Evaluation and Development, Manhattan, KS.
Cho, J. & Baek, W. (2019). Identifying Factors Affecting the Quality of Teaching in Basic Science Education: Physics, Biological Sciences, Mathematics, and Chemistry. Sustainability. 11, 3958.
Clark, D. (1993). Teacher evaluation: a review of the literature with implications for educators, Seminar in Elementary Education, California State University at Long Beach, Long Beach, CA, Spring.
Cohen, P. (1981). Student ratings of instruction and student achievements, a meta-analysis of multisection validity studies. Review of Education Research, 51 (Fall, 1081), 281–309.
Cranton, P. & Smith, R.A. (1986). A new look at the effect of course characteristics on student ratings of instruction, American Educational Research Journal, Spring, pp. 117-28.
Cranton, P. & Smith, R.A. (1990). Reconsidering the unit of analysis: a model of student ratings of instruction, Journal of Educational Psychology, 82 (2), pp. 207-12.
Cuthbert, P.F. (1996). Managing service quality in Higher Education: is SERVQUAL the answer? Part 2. Managing Service Quality, 6 (3), 31-35.
Dardiri A. (2017) Teacher performance and work environment in the instructional process in vocational school. Green Construction & Engineering Education For Sustainable Future: Proceedings of the Green Construction & Engineering Education (GCEE) Conference 2017
DeBerg, C.L. & Wilson, J.R. (1990). An empirical investigation of the potential confounding variables in student evaluation of teaching, Journal of Accounting Education, 8 (1), pp. 37-62.
Diamond, I. (2013). Effective Learning & Teaching in UK Higher Education (The Higher Education Academy), Page 14-17. Professor Sir Ian Diamond, speaking at the 2nd Annual UUK Conference on Efficiency, 26 February 2013. London: Universities UK.
Duarte, F.P. (2013). Conceptions of Good Teaching by Good Teachers: Case Study from an Australian University
Elizabeth Brooke (2013). Empowering Teacher Effectiveness: Five Key Factors for Success. Vice President of Education and Research, Lexia Learning.
Fathi M. Ihmeidah, Aieman Ahmad Al-Omari & Khloud A. Al-Dababneh (2010). Attitudes toward Communication Skills among Students'-Teachers' in Jordanian Public Universities, Australian Journal of Teacher Education: 35 (4), Article 1.
Fink, L.D. (2003). Creating significant learning experiences: An integrated approach to designing college courses. San Francisco: CA: John Wiley & Sons, Inc.
Ford, J.B., Joseph, M. & Joseph, B. (1999) Importance-performance analysis as a strategic tool for service marketers: the case of service quality perceptions of business students in New Zealand and the USA, The Journal of Services Marketing, 13 (2), pp. 171-86.
Frey, P.W. (1973). Student ratings of teaching: validity of several rating factors, Science, 182 (4107), pp. 83-85.
Frey, P.W. (1974). The ongoing debate: student evaluation of teaching, Change, 6 (1), pp. 47-49.
Frey, P.W. (1978). A two-dimensional analysis of student ratings of instruction, Research in Higher Education, 9 (1), pp. 69-91.
Gage, N.L. (1961). The appraisal of college teaching. Journal of Higher Education. 32.17-22.
Goldberg, G. & Callahan, J. (1991). Objectivity of student evaluations of instructors. Journal of Education for Business. 66 (6), 377-378.
Green, B., Calderon, T. & Reider, B. (1998). A content analysis of teaching evaluation instruments used in accounting departments, Issues in Accounting Education, 13 (1), pp. 15-30.
Green, B.P., Calderon, T.G., Gabbin, A.L. & Habegger, J.W. (1999). Perspectives on Implementing a Framework for Evaluating Effective Teaching. Journal of Accounting, 17 (1)
Ham, L. & Hayduk, S. (2003). Gaining competitive advantages in higher education: analyzing the gap between expectations and perceptions of service quality. International Journal of Value-Based Management, 16 (3), 223-242.
Hamid, J.A. & Pihie, Z.A.L. (2004). Students' Perception of the Quality of Teaching and Learning in Business Studies Programs. Pertanika J. Soc. Sci. & Hum. 12 (1): 71-86
Hamre, B.K., Goffin, S.G. & Kraft-Sayre, M. (2009). Classroom Assessment Scoring System Implementation Guide: Measuring and Improving Classroom Interactions in Early Classroom Settings.
Hill, F.M. (1995). Managing service quality in higher education: the role of the student as primary consumer, Quality Assurance in Education, 3 (3), pp. 10-21.
Holtfreter, R.E. (1991). Student rating biases: are faculty fears justified? The Woman CPA, Fall, pp. 59-62.
Hooper, P. & Page, J. (1986) Measuring teaching effectiveness by student evaluation, Issues in Accounting Education, Spring, pp. 56-64.
Ismail MA-A, Mohd Fakri NMR, Mohammad JA-M, Mat Nor MZ, Ahmad A, Yusoff MSB (2018). Teaching effectiveness during lectures in Universiti Sains Malaysia School of Medical Sciences. Education in Medicine Journal. 10 (3): 13–22.
Joseph, M., Yakhou, M. & Stone, G. (2005). An educational institution's quest for service quality: customers' perspective. Quality Assurance in Education 13(1): 66-82.
Kelley, H.H. (1950). The warm-cold variable in first impressions of persons, Journal of Personality and Social Psychology, 18 (3), pp. 431-439.
Kıymet Selvi (2012). Creation and Construction of Knowledge in Learning-Teaching Process. In Phenomenology and the Human Positioning in the Cosmos. pp. 167-179
Ko J., Sammons P. & Bakkum L. (2014). Effective Teaching. Education Development Trust.
Kogan, Lori R., Schoenfeld-Tacher, R. & Hellyer, Peter W. (2010) Student Evaluations of Teaching: Perceptions of Faculty Based on gender, position, and rank. Teaching in Higher Education 15 (6), pp. 623-636
Koh, H. & Tan, T. (1997). Empirical investigation of the factors affecting SET results, International Journal of Educational Management, 11 (4), pp. 170-8.
Kwek Choon Ling, Lau Teck Chai & Tan Hoi Piew (2010) The inside-out' and 'outside-in' approaches on students' perceived service quality: an empirical evaluation, Management Science and Engineering, 4 (2), pp. 1-26.
Lagrosen, S., Seyyed-Hashemi, R. & Leitner, M. (2004) Examination of the dimensions of quality in higher education, Quality Assurance in Education, 12 (2), pp. 61-9.
Langbein, L.I. (1994). The validity of student evaluations of teaching. Political Science and Politics, September, 1994
Le Blanc, G. & Nguyen, N. (1997). Searching for excellence in business education: an exploratory study of customer impressions of service quality, International Journal of Educational Management, 11 (2), pp. 72-9.
Lewis, K.G., Woodward, P. & Bell, J. (1988). Teaching business communication skills in large classes. Journal of Business Communication, 25 (1), 65–86.
Liaw, S. & Goh, K. (2003). Evidence and control of biases in student evaluations of teaching, The International Journal of Educational Management, 17 (1), pp. 37-43.

Lizzio, A., Wilson, K. & Simons, R. (2002). University students' perceptions of the learning environment and academic outcomes: implications for theory and practice, Studies in Higher Education, 27 (1), pp. 27-52.
Marsh, H.W. & Dunkin, M. (1992). Students' evaluations of university teaching: A multidimensional perspective, in Smart, J.C. (Ed.), Higher Education: Handbook on Theory and Research, Vol. 8, Agathon Press, New York, NY, pp. 143-234.
Marsh, H.W. & Roche, L.A. (1997). Making students' evaluations of teaching effectiveness effective. American Psychologist, 1997, (52) pp. 1187-1197.
Mart, C.T. (2017). Student Evaluations of Teaching Effectiveness in Higher Education. International Journal of Academic Research in Business and Social Sciences, 7 (10), pp. 57-60
Mukherji, S. & Rustagi, N. (2008). Teaching evaluations: Perceptions of students and faculty. Journal of College Teaching & Learning, 5 (9), 45–54.
Mulford, C. & Schneider, A. (1988). An empirical study of structural and controllable factors affecting faculty evaluations, Advances in Accounting, Vol. 6, pp. 205-15.
Neumann, Y. & Neumann, L. (1983). Characteristics of academic areas and students' evaluation of instruction, Research in Higher Education, pp. 323-334.
Newton, J. (1988). Using student evaluation of teaching in administrative control: the validity problem, Journal of Accounting Education, Vol. 6, pp. 1-14.
Ovando, M.N. (1989). An effective faculty development program: It can be done. Paper presented at the annual conference of the National Council of States on In service Education, San Antonio, Texas.
Pariseau, S.E. & McDaniel, J.R. (1997). Assessing service quality in schools of business, International Journal of Quality & Reliability Management, 14 (3), pp. 204-218
Patricia H. (2008). Pennsylvania State University. learningdesign@psu.edu. Retrieved from http://ets.tlt.psu.edu/learningdesign/syllabus
Peng, P.J. & Samah, A.J.A. (2006). Measuring students' satisfaction for quality education in a e-learning university, Unitar E-Journal, 2 (1), pp. 11-21.
Peter J. Goodhew (2010). Teaching Engineering: All You Need to Know about Engineering Education. The Higher Education Academy.
Robert Coe, Cesare Aloisi, Steve Higgins & Lee Elliot Major (2014). What Makes Great Teaching: Review of the Underpinning Research
Russell, M. (2005). Marketing Education: A review of service quality perceptions among international students. International Journal of Contemporary Hospitality Management, 17 (1), pp. 65-77.
Ryan, J.M. & Harrison P.D. (1995). The relationship between individual instructional characteristics and the overall assessment of teaching effectiveness across different instructional contexts, Research in Higher Education, 36 (5), pp. 213-228.
Sang, H.B. (2007). The relationship between ISO 9000 participation and educational outcomes of schools, Quality Assurance in Education, 15 (3), pp. 251-270.
Sangeeta Sahney, D.K. Banwet & S. Karunes (2012), "The Usefulness of Student Evaluations for Enhancing the Effectiveness of Teaching of Financial Accounting Students at a South African University - South Africa"
Seldin, P. (1989). How colleges evaluate professors, American Association for Higher Education Bulletin, 41 (7), pp. 3-7.
Seldin, Peter (1993). How Colleges Evaluate Professors, 1983 v. 1993. POD Network Conference Materials. 110.
Serin, H. (2019) Student Evaluations of Teaching Effectiveness: An Instrument to Increase Teaching Quality in Higher Education. International Journal of Social Sciences & Educational Studies, 5 (4). pp. 168-173
Shapiro, D. (1991). The effects of explanations on negative reactions to deceit, Administrative Quarterly, Vol. 36, pp. 614-30.
Shevlin, M., Banyard, P., Davies, M. & Griffiths, M. (2000). The validity of student evaluation of teaching in higher education: love me, love my lectures? Assessment & Evaluation in Higher Education, 25 (4), pp. 397-405.
Simpson, R. (1995). Uses and misuses of student evaluations of teaching effectiveness. Innovative Higher Education, 20 (1), 3–5.
Smith, F. (1995). Let's declare education a disaster and get on with our lives. Phi Delta Kappan, 76, 584-590.
Sohail, M.S. & Shaikh, N.M. (2004). Quest for excellence in business education: a study of student impressions of service quality, The International Journal of Educational Management, 18 (1), pp. 58-65.
Soutar, G. & McNeil, M. (1996). Measuring service quality in a tertiary institution. Journal of Educational Administration, 34 (1), 72-82.
Stratton, W.O. (1990) A model for the assessment of student evaluations of teaching, and the professional development of faculty, The Accounting Educators' Journal, Summer, pp. 77-101.
Strong, M., Gargani, J. & Hacifazlioglu, O. (2011). Do We Know a Successful Teacher When We See One? Experiments in the Identification of Effective Teachers. Journal of Teacher Education, 62 (4), 367–382.
Toby, S. (1993). Class size and teaching evaluation or, the 'general chemistry effect revisited', Journal of Chemical Education, June, pp. 465-6.
Van der Merwe, D.C. (2012). The Usefulness of Student Evaluations for Enhancing the Effectiveness of Teaching of Financial Accounting Students at a South African University. In Accounting in Africa. Published online: 9 Mar 2015; 107-126.
Vernon, P.E. (1964). Personality Assessment: a critical survey (London, Methuen).
Wei Hong & Shen Jiliang (2002). Study on Teaching Characteristics of Effective University Teacher. Journal of Southwest China Normal University (Humanities and Social Sciences Edition), (28) 33-36.
Whitworth, J.E., Price, B.A. & Randall, C.H. (2002). Factors that affect college of business student opinion of teaching and learning, Journal of Education for Business, May/June, 282-289.
Yunker, P.J. & Sterner, J. (1988). A Survey of Faculty Performance Evaluation in Accounting, Accounting Educators' Journal, Fall, pp. 63-71.
Yunker, P.J. & Yunker, J.A. (2003). Are student evaluations of teaching valid? Evidence from an analytical business core course. Journal of Education for Business 78: 313-317.

Project-based Community of Inquiry for Effective Online Graduate Course on Life Cycle Assessment

Article history
Received
17 September 2021
Received in revised form
30 September 2021
Accepted
5 October 2021
Published online
30 November 2021

Peng Yen Liew[a*], Lian See Tan[a], Chan Choong Foong[b], Nor Ruwaida Jamian[a]
[a]Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra, 54100 Kuala Lumpur, Malaysia
[b]Medical Education and Research Development Unit, Faculty of Medicine, University of Malaya, Kuala Lumpur, Malaysia
**pyliew@utm.my*

Abstract
This article aimed to present the improvements on the instructional design of a postgraduate course, namely Life Cycle Assessment (LCA), for effective content delivery in online teaching and learning due to COVID-19 pandemic. The community of inquiry framework was used as the basis for this improvement. It was aided by project-based learning to enhance the educational experiences and improve content delivery efficiency. Conventional active learning teaching pedagogy was maintained in the early part of the course. Next, an open-ended project became the pillar of the second part of the course for performing a comparative LCA in a team. To ensure all students have high individual accountability, each team member performed a LCA study independently for a sub-scope of the project. Meanwhile, their teammates supported each other as each sub-scope is interdependent on the project. WhatsApp was used to promote interactions between students-students and students-instructors to provide just-in-time feedback, and weekly consultations were offered to students to monitor student progress. Based on the course evaluation, the students felt optimistic about the changes. They agreed that these new delivery methods helped them in mastering the subject matter.

Keywords: Community of Inquiry; Project-based Learning; Online Learning.

Introduction

The COVID-19 pandemic has catalysed online teaching and learning practices in higher education institutions around the world (Adnan & Anwar, 2020; Chakraborty, Mittal, Gupta, Yadav, & Arora, 2021). Due to national lockdown, online classes replace physical classes through synchronous and asynchronous learning. As a result, the learning management system and telecommunication apps become essential tools for sustaining the online teaching and learning practices (Mishra, Gupta, & Shree, 2020).

Literature

The Community of Inquiry (CoI) framework is an established framework for planning online educational experiences (Garrison, Anderson, & Archer, 1999). "Presence" is vital in the framework to engage learners in sustaining their concentration, which includes cognitive, social, and teaching presences (Garrison & Arbaugh, 2007) (Figure 1). Arbaugh, Bangert, and Cleveland-Innes (2010) found that student perceptions support the CoI framework usage in online teaching and learning practices.

Cognitive presence is defined as knowledge construction through continuous communications in the learning environment (Stewart, 2019). Cognitive presence involves four stages in inquiry-based learning, which are (1) triggering event, usually a problem or learning issue to be explored by learners, (2) exploration, where the learners explore the problem or issue individually or in a team, (3) integration, in which the learners bring together information from the previous stage to construct their knowledge, and (4) resolution, in which the learners apply newly gained knowledge in the context of the subject matter (Garrison & Arbaugh, 2007).

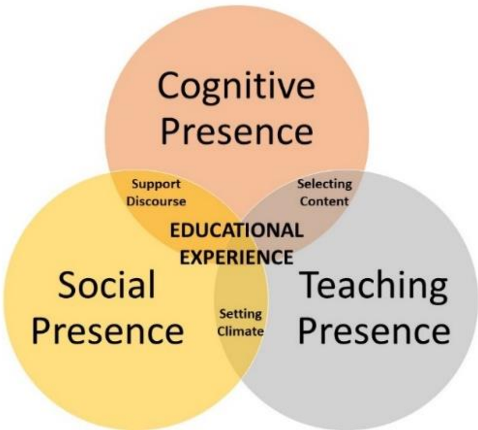


Figure 1. Community of Inquiry Model (Garrison & Arbaugh, 2007)

Social presence is defined as the social and emotional connection among the learners and instructors in the learning environment (Cooper, Forino, Kanjanabootra, & von Meding, 2020). The presence is categorised into affective expression, open communication and group cohesion (Garrison & Arbaugh, 2007). Past researchers have extensively studied this element as it is one of the most powerful features in the CoI framework. Furthermore, social presence provides a safe environment for the learners to develop their self-confidence in constructing new knowledge (Li, 2015).

Teaching presence refers to the instructional design provided by the instructors in their efforts to facilitate knowledge construction among the learners (Garrison, 2016). This element consists of three parts, which include (1) instructional design and organisation, (2) facilitating discourse, and (3) direct instruction (Anderson, Rourke, Garrison, & Archer, 2019). Furthermore, collaborative activities enable learners to have higher social presence and feel more incredible that a learning community has been created (Redmond & Lock, 2006). Therefore, the instructors could integrate inquiry-based learning (teaching presence) into the CoI framework to enhance social connection between learners and instructors (social presence) alongside the efforts to ensure new knowledge can be constructed effectively (cognitive presence).

Based on the past research, Shea and Bidjerano (2010) propose a positive relationship between the three elements in the CoI framework (Figure 2). Past research shows that teaching and social presences have a positive impact on the cognitive presence. The teaching presence via the instructional design play a central role in directly affecting the perception on the social and cognitive presences, which are important to achieve the intended learning outcomes and to maintain a positive learning environment (Garrison, Cleveland-Innes, & Fung, 2010).

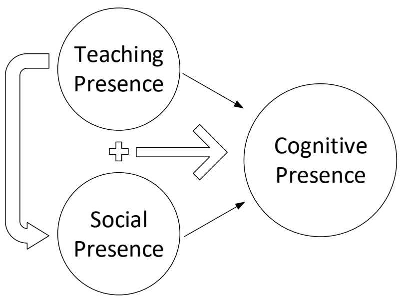


Figure 2. Relationship between elements in Community of Inquiry framework (Shea & Bidjerano, 2010)

Project-based learning (PjBL) is an effective pedagogy that integrates real-life application. The project is commonly defined with several key features, including it is a realistic or real-world project requires critical thinking and problem solving (Uziak, 2016). It has explicit objectives with individual and collective learning, and the project needs to be completed in a given time frame. The PjBL is always grounded with student-directed learning with instructor as facilitator to scaffold, motivate and monitor the progress (Bell, 2010). Since the PjBL is conducted in a team setup, it requires students work collaboratively with their teammates in achieving shard goals. The students need to communicate and interact with their teammates due to the interdependency of the project.

The PjBL is an instructional design (teaching presence) to promote cooperatively support having the students in team to (social presence) the cognitive presence in the CoI framework for enhancing learning experiences.

Problem

Life Cycle Assessment (LCA) is a core course for the Master of Sustainable Systems degree in the Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia. Students who enrol in the programme have diverse educational backgrounds, such as engineers, environmentalists, architects, biologists, and chemists. The course requires students to understand the fundamental concepts of LCA. The course expects students to perform all steps in an LCA using appropriate software after completing the course. In the 2020/2021 academic session, there were 13 students enrolled in the course, including five international and eight local students. There were five males and eight females in the class. The course learning outcomes were listed as follows:

- CLO1: Simulate an LCA study, understand its strengths, weaknesses, and appropriate use (assessments: assignments, tests)
- CLO2: Evaluate environmental impacts of a product, technology, or system by applying the LCA methodology (assessments: assignments, tests)
- CLO3: Perform an LCA on a system using publicly available data and software (assessments: project reports, presentations)

In previous semesters, the instructors conducted the course using student-centred learning through book-end lectures (Smith, 2000). It was observed that the steps to perform LCA using the LCA framework (Figure 3) are highly interdependent (Pryshlakivsky & Searcy, 2013), which some content in the weekly classes seemed to be redundant. The teaching and learning became less effective when the theory component was explained with simplistic examples or simplistic manual calculations. In addition, the application of the LCA methodology (project) was superficial. Students completed the project with minimal guidance using demo-version of a commercial LCA software, namely OpenLCA software.

In the 2020/2021 academic session, the course was forced to adopt a complete virtual learning mode due to national lockdown during the COVID-19 pandemic. Hence, incorporating the CoI framework with PjBL aimed to enable students to undergo an effective teaching and learning process.

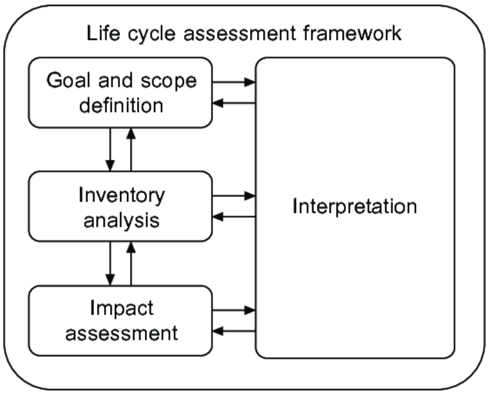


Figure 3. LCA framework (Pryshlakivsky & Searcy, 2013)

Design and Implementation

The course was restructured for effective content delivery. The course curriculum was divided into the theoretical component (6 weeks) and project (application) (8 weeks) component, as shown in Table 1.

The theoretical component covered the environmental management systems (EMS), roles of LCA in EMS, international standards in LCA, terms and concepts in LCA, steps in the LCA framework. These virtual classes were conducted based on the book-end approach to ensure that learners paid attention during the classes. In this component, the learners were given tasks for step-by-step analysing published LCA case studies based on learners' interests. For every LCA step, the learners analysed how the literature case studies were conducted, and they present their findings in the virtual class. These tasks aimed to ensure that learners can learn all the LCA steps by analysing case studies and various examples on their efforts and by listening to explanations from their peers.

The lectures also focused on cooperative project-based learning. The learners were divided into teams with 3 to 4 members, and each team was required to conduct a comparative LCA study for a selected product or process. The problem was designed to be open-ended. The learners can freely choose their teammates and select any topic that they were interested in based on their previous educational background or working experiences. For example, the environmental impacts of producing 1 MW of electricity from renewable energy generation routes (solar PV, biomass and biogas) are studied from cradle to crave. The project was divided into three parts: comparative LCA's goal and scope (Phase 1 – teamwork), LCA analysis (Phase 2- individual work) and comparison (Phase 3 – teamwork).

In Phase 1 of the project, each team discussed the product to be studied, which the differences in the individual scope for each member should be identified.

Table 1. Brief instructional design for LCA subject

Week 1-6 (Theoretical Component)
• The virtual online classes are conducted with active learning approaches. • Learners are given tasks to analyse selected literature case studies based on the goal and scope, inventory analysis, impact assessment and the interpretation presented. • Learners present their analysis findings, while peers learn from the case study of the presenters. • Learners are required to install and learn an open-source LCA software using examples provided by the software developers. Instructors monitor each student's progress every week.
Week 7-8 (Project Component - Phase 1 – Project Conception)
• The learners are grouped into teams with 3 to 4 members. The team autonomously decides the product or process to be investigated as a comparative LCA study. The team must set shared goals and scopes for the comparative study, with a similar process boundary and goal but using different process routes or raw materials or products. • Each member in the team is assigned with one scope for performing the LCA study, which later could be compared. • Outcomes of each team are presented. Each presentation receives impromptu feedback from the instructors.
Week 9-12 (Project Component - Phase 2 – Individual LCA)
• Learners must use the open-source LCA software to perform individual LCA studies for the assigned scope. • Individual progress is presented, and students receive feedback from the instructors to ensure that the teammates' assumptions are aligned. All learners are required to submit a report describing the results of the individual LCA studies. • To ensure the LCA studies are comparable, the members must have the same assumptions for their study. Therefore, the learners must communicate with their teammates.
Week 13-14 (Project Component - Phase 3 – Comparative LCA)
• Learners gather as a team and compare the results between individual scopes. • The team is requested to submit a report comparing the environmental impacts of the processes for the same functional unit and system boundary.

The problem definition, functional unit, system boundary, impact categories and assumptions were harmonised among team members to ensure the LCA studies will be comparable. Subsequently, each team member was assigned one of the scopes, and he/she was required to perform an individual LCA study. An example is given as follows: the overall team's scope was setup to produce the same amount of product (functional unit), for instance 1 MW of electricity production. Next, student A took the scope of studying the environmental impacts of producing 1 MW of electricity from solar PV, while student B studied on generation from biomass, and student C studied for electricity generation from biogas. Without setting the problem correctly, the team could not complete Project Phase 3 in a team. A team presentation session was arranged to provide facilitation and feedback to the learners, which the learners had opportunities to learn from other teams.

Once the problem identification was made in the team, the individual learners were expected to perform an LCA study using open-source LCA software in phase 2. The learners were expected to further discuss in the team to refine the problem and assumptions as a comparable study had to be done. A progress presentation was conducted in the project duration to ensure that the learners worked as planned and instructors' feedback was provided on time. In other weekly class hours, the instructors met with all learners to listen to their progress and provided feedback. The team members needed to ensure synchronisation in their work within the team. During the presentation or progress meetings, instructors took opportunities to link the project to the theories and ensured learners master the theories through examples. Lastly, the learners were expected to produce an individual report to demonstrate their mastery of the LCA steps and software.

This individual project phase ensured individual accountability and for learners to achieve targeted learning outcomes. In addition, this project phase was designed to connect the teammates to form a social presence. The learners had to consult their team members, who face similar difficulties due to solving a similar problem, promoting interdependence between team members.

In the last phase of the project (Phase 3), the learners gathered to compare each member's results. As a continuation of previous example given, the environmental impacts due electricity generating from different renewable energy sources (e.g., solar versus biomass versus biogas) were compared. Each member presented the impacts for one type of energy source in Phase 2 and at the same time, they listened presentations of other types of energy source. This phase helped learners deepen their understanding of their own work and appreciate the different scopes completed by the team members. In addition, at this stage, the learners were expected to appreciate the importance of teamwork.

Besides that, the instructors were active in the learning management system in providing various resources to the learners (synchronous learning). Meanwhile, the instructors initiated an open discussion group using an online messaging application (i.e., WhatsApp). The learners were encouraged to ask questions on the LCA concept or software in the group. Classmates were encouraged to help their classmates before the instructors intervened on the same questions.

A questionnaire which aimed to explore student perceptions on the course was distributed to the students via Google Form after the course completion. Eleven students (85% response rate) answered the questionnaire. They consented to publish the results and understood perseverance of the anonymity.

The questionnaire consisted of six Likert-scale questions and six open-ended questions. The Likert-scale questions were modified from a validated instrument in measuring student perceptions of an educational environment (Roff et al., 1997). The original instrument was validated and used in different countries (Miles, Swift, & Leinster, 2012). The six questions asked were: (1) Discussions in WhatsApp helps to develop my competence, (2) Working in groups - having group members to seek help from or to exchange ideas, helps to develop my competence, (3) Weekly consultations with lecturers helps to develop my competence, (4) A project solving a real industrial problem, helps to develop my competence, (5) Individual assessment (report) helps to develop my competence. Each question had 5 scales ranged from 1 (strongly disagree), 2 (disagree), 3 (unsure), 4 (agree) to 5 (strongly disagree).

Meanwhile, for each Liker-scale question, a corresponding open-ended question was created to allow students to elicit their rationales for the Likert-scale responses. The open-ended questions were designed using hypothetical questions (Merriam & Tisdell, 2015). An open-ended question should be designed to obtain an explanation and avoid imposing ideas on the respondents (Merriam & Tisdell, 2015). An example of an open-ended question was, “If you were the lecturer, would you arrange to work in groups again for next semester? Why? Please elaborate and give examples.”

Results and Discussion

The course with new delivery methods was successfully implemented. The student overall achievement of the previous (n=5) and current (n=13) semesters has improved from 76 marks to 80 marks. One student may be seen as an outlier for not achieving the targeted overall attainment level; he had issues accessing the online learning environment during the COVID-19 pandemic.

Table 2. Students feedback on various features in the project-based community of inquiry

Real-life Project (Cognitive Presence)	
"A project solving a real industrial problem, helps to develop my competence." Strongly agree: 91% Unsure: 9%	• "It is interesting to learn and gain new skills as well as exposing students to the real problems." • "It provides the real situation of an actual report to apply in real problem later on." • "First of all, it was fun. Since it's a real scale project, I always felt connected with the situation. I went through several write-ups, which enrich my knowledge in a short time. Secondly, it was a new experience to learn new software. So definitely, these two (methods) meant a lot."
Project – Individual LCA Phase (Cognitive Presence)	
"Individual assessment (report) helps to develop my competence." Strongly agree: 64% Agree: 36%	• "Through the individual reports, the whole idea of an LCA study became very clear. Since an individual did all the tasks in the individual report, this makes a clear-cut idea for all about their respective topic." • "(Individual report) assesses the student individually and find out who did not do the work. Group projects might benefit the incompetent members while other people did most of the work. An individual assessment can ensure the fairness of marks given."
Project – Comparative LCA Phase (Cognitive Presence)	
"Group assessment (report) helps to develop my competence." Strongly agree: 82% Agree: 18%	• "The result comparison for the group report seemed good and also very technical. Through the group report, we learnt how a comparative LCA looks like and what parameters should be looked for during the result discussion, simulation and analysis." • "We can share our knowledge within the group. Moreover, I agree with the proportion of group and individual works in this semester LCA." • "It helps each member to share and solve the problem together."
Whatsapp Group (Social Presence)	
"Discussions in WhatsApp helps to develop my competence." Strongly agree: 55% Agree: 27% Unsure: 18%	• "It's a convenient way to do so since physical classes are not available. The information needed can be spread faster." • "I would promote discussion in WhatsApp since this is the fastest route to reach the lecturers. Other than that, instructors provide speedy responses anytime we encounter problems during our time doing assignments." • "Some issue brought up by other classmates, and the discussion may help to clear some doubts for other classmates." • "It promotes communication between students, especially when one encountered a problem, and another has encountered and managed to solve the same problem."
Team-based learning (Social Presence)	
"Working in groups - having group members to seek help from or to exchange ideas, helps to develop my competence." Strongly agree: 64% Agree: 36%	• "Sometimes it is easier and comfortable to discuss some topics in a small group." • "Group work was the best idea. Because students would not feel pressurised with the new subject and always has someone to discuss further. I liked the group work theme. For this, the in-depth knowledge gain was possible." • "Working in groups prompt discussion within the group. Students who are shy to discuss in WhatsApp group (with instructors) can discuss within their members, and the discussion will be more related to the chosen topic." • "It allows the sharing of information from different perspectives of certain topics from the group members. Since the group members are from various backgrounds, different inputs are obtained through the discussion done. The experiences and perspectives enable more interesting topics to be discussed and broaden the inputs."
Weekly Consultation with Instructor (Teaching Presence)	
"Weekly consultations with lecturers help to develop my competence." Strongly agree: 64% Agree: 36%	• "Sometimes we don't know if what we're doing is correct, so with the weekly consultation, at least we can consult midway our progress (whether) is correct or not." • "Weekly consultations help students to keep on track as well as helping them to (have) more understanding on the topic." • "The weekly consultations seemed very effective towards clearing our thought. For example, every homework had been discussed quite precisely during the classes. It was a very nice idea, I must say.

Student responses in the questionnaire were analysed and shown in Table 2. The results were matched to the cognitive, social and teaching presences in the CoI framework. The majority of the students agreed that the newly introduced delivery methods had improved their learning experience in the course.

The open-ended industrial project, individual project report on individual LCA study and team project report on comparative LCA study were evidence of cognitive presence (Table 3). The students appreciated these methods for supporting their learning. The students concluded that the industry-related project facilitates them to master the LCA method better and prepared them for actual usage of the LCA methodology in the future. Meanwhile, the individual project was well accepted by all students because it helped ensure all individual students could master the subject matter. The individual assessment differentiated the competency and contribution of every team member in the project. Lastly, the students highly recognised the project team report/assessment, which technically exposed the students to an additional concept: the comparative LCA. The team analysed the results from individual LCA in this part, which helped the students to understand parameters to be compared. Although online learning was known to have a lower commitment from the students, the students agreed that the team project formed a supporting system among the team members throughout the learning process.

The open discussion group using WhatsApp and team-based learning were planned to promote social presence in the course. Some students affirmed that the active use of the open discussion group in WhatsApp helped their learning process through impromptu discussion with classmates and guidance from the instructors. Findings of this study echo past research (Qamar, Riyadi, & Wulandari, 2019) that WhatsApp discussions help promote interactions between the students. Universities unofficially adopt WhatsApp, yet it is user friendly to students (Mpungose, 2020). On the other hand, some students may not appreciate the use of the open discussion group, as they believed that face-to-face interaction will be more effective than the online platform. Next, most students felt that team-based learning is helpful. This was because the team members were helping each other in solving technical issues in the software. Moreover, as students were from mixed educational backgrounds, team-based activities during synchronous sessions were given additional credit for the reason it allowed the students to learn knowledge from different fields of study.

Lastly, the teaching presence was a critical element in the CoI framework for effective online learning. The instructors needed to design and support the learning experiences for the students. The students provided positive comments that the instructional design embedded with project-based learning has supported their learning process. In addition, students appreciated the instructor's impromptu feedback in the online discussion group. Moreover, the weekly consultation took place during synchronous learning classes was believed to help the students understand and progress in their assignments and project through just-in-time feedback. Effective feedback has characteristics of being relevant, immediate, factual, helpful, respectful, tailored and encouraging (Ovando, 1994).

Conclusion

Using the CoI framework for an online postgraduate course can improve student achievement and learning experiences during the COVID-19 pandemic. Project-based learning complements the CoI framework in creating proper teaching presence to achieve the cognitive presence while encouraging social presence in the virtual classroom environment.

This study is imperfect. Future implementation of the LCA course may consider using self and peer assessments (Foong & Liew, 2020) or reflection journals (Boud, Keogh, & Walker, 2013) to avoid free-riding among the team members, and help them reflect their attitudes with the aim to further improve their engagement throughout the course.

References

Adnan, M., & Anwar, K. (2020). Online Learning amid the COVID-19 Pandemic: Students' Perspectives. *Online Submission, 2*(1), 45-51.

Anderson, T., Rourke, L., Garrison, R., & Archer, W. (2019). Assessing Teaching Presence in a Computer Conferencing Context. *Online Learning, 5*(2). doi:10.24059/olj.v5i2.1875

Arbaugh, J. B., Bangert, A., & Cleveland-Innes, M. (2010). Subject matter effects and the Community of Inquiry (CoI) framework: An exploratory study. *The Internet and Higher Education, 13*(1), 37-44. doi:https://doi.org/10.1016/j.iheduc.2009.10.006

Bell, S. (2010). Project-Based Learning for the 21st Century: Skills for the Future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 83*(2), 39-43. doi:10.1080/00098650903505415

Boud, D., Keogh, R., & Walker, D. (2013). *Reflection: Turning experience into learning*: Routledge.

Chakraborty, P., Mittal, P., Gupta, M. S., Yadav, S., & Arora, A. (2021). Opinion of students on online education during the COVID-19 pandemic. *Human Behavior and Emerging Technologies, 3*(3), 357-365. doi:https://doi.org/10.1002/hbe2.240

Cooper, V. A., Forino, G., Kanjanabootra, S., & von Meding, J. (2020). Leveraging the community of inquiry framework to support web-based simulations in disaster studies. *The Internet and Higher Education, 47*, 100757. doi:https://doi.org/10.1016/j.iheduc.2020.100757

Foong, C. C., & Liew, P. Y. (2020). Investigating the Reliability and Usefulness of Self- and Peer Assessments of a Capstone Design Project. *International Journal of Engineering Education, 36*(6), 1850-1861.

Garrison, D. R. (2016). *E-learning in the 21st century: A community of inquiry framework for research and practice*: Taylor & Francis.

Garrison, D. R., Anderson, T., & Archer, W. (1999). Critical Inquiry in a Text-Based Environment: Computer Conferencing in Higher Education. *The Internet and Higher Education, 2*(2), 87-105. doi:https://doi.org/10.1016/S1096-7516(00)00016-6

Garrison, D. R., & Arbaugh, J. B. (2007). Researching the community of inquiry framework: Review, issues, and future directions. *The Internet and Higher Education, 10*(3), 157-172. doi:https://doi.org/10.1016/j.iheduc.2007.04.001

Garrison, D. R., Cleveland-Innes, M., & Fung, T. S. (2010). Exploring causal relationships among teaching, cognitive and social presence: Student perceptions of the community of inquiry framework. *The Internet and Higher Education, 13*(1), 31-36. doi:https://doi.org/10.1016/j.iheduc.2009.10.002

Li, K. M. (2015). Learning styles and perceptions of student teachers of computer-supported collaborative learning strategy using wikis. *Australasian Journal of Educational Technology, 31*(1).

Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation*: John Wiley & Sons.

Miles, S., Swift, L., & Leinster, S. J. (2012). The Dundee Ready Education Environment Measure (DREEM): a review of its adoption and use. *Medical Teacher, 34*(9), e620-e634.

Mishra, L., Gupta, T., & Shree, A. (2020). Online teaching-learning in higher education during lockdown period of COVID-19 pandemic. *International Journal of Educational Research Open, 1*, 100012. doi:https://doi.org/10.1016/j.ijedro.2020.100012

Mpungose, C. B. (2020). Emergent transition from face-to-face to online learning in a South African University in the context of the Coronavirus pandemic. *Humanities and Social Sciences Communications, 7*(1), 113. doi:10.1057/s41599-020-00603-x

Ovando, M. N. (1994). Constructive feedback: A key to successful teaching and learning. *International Journal of Educational Management*.

Pryshlakivsky, J., & Searcy, C. (2013). Fifteen years of ISO 14040: a review. *Journal of Cleaner Production, 57*, 115-123.

Qamar, K., Riyadi, S., & Wulandari, T. (2019). Utilization of whatsapp application as discussion media in blended learning. *Journal of Education and Learning (EduLearn), 13*, 370-378. doi:10.11591/edulearn.v13i3.8412

Redmond, P., & Lock, J. V. (2006). A flexible framework for online collaborative learning. *The Internet and Higher Education, 9*(4), 267-276. doi:https://doi.org/10.1016/j.iheduc.2006.08.003

Roff, S., McAleer, S., Harden, R. M., Al-Qahtani, M., Ahmed, A. U., Deza, H., . . . Primparyon, P. (1997). Development and validation of the Dundee ready education environment measure (DREEM). *Medical Teacher, 19*(4), 295-299.

Shea, P., & Bidjerano, T. (2010). Learning presence: Towards a theory of self-efficacy, self-regulation, and the development of a communities of inquiry in online and blended learning environments. *Computers & Education, 55*(4), 1721-1731. doi:https://doi.org/10.1016/j.compedu.2010.07.017

Smith, K. A. (2000). Going Deeper: Formal Small-Group Learning in Large Classes. *New Directions for Teaching and Learning, 2000*(81), 25-46. doi:https://doi.org/10.1002/tl.8103

Stewart, M. K. (2019). The Community of Inquiry Survey: An Assessment Instrument for Online Writing Courses. *Computers and Composition, 52*, 37-52. doi:https://doi.org/10.1016/j.compcom.2019.01.001

Uziak, J. (2016). A project-based learning approach in an engineering curriculum. *Global Journal of Engineering Education, 18*(2), 119-123.

Designing an Experiential Learning with Simulations and Games to Improve Education in an Undergraduate Engineering Major

Article history
Received
12 September 2021
Received in revised form
11 October 2021
Accepted
14 October 2021
Published online
30 November 2021

Alina Zapalska
U.S. Coast Guard Academy
alina.m.zapalska@uscga.edu

Abstract
This paper illustrates an experiential learning exercise that is designed to be played in an engineering undergraduate program. The author uses simulation that creates an active and experiential learning environment in which individual teams make decisions based on imperfect information and conflicting goals. The simulation allows players to control certain aspects of the information flow relevant to the market, to develop relevant business strategies and communication skills, and to establish understanding of ethical values that are relevant to business environment. The simulation was designed to allow engineering students to advance and practice business skills that are essential for engineers to stay successful in an increasingly competitive business environment. The objective is to extract maximum learning from the experience using an experiential learning model. This paper contributes to the literature on designing active learning with the use of games and simulations while utilizing the Kolb experiential learning model

Keywords: Simulation game, experiential learning, undergraduate engineering education, strategy and ethics.

Introduction

Traditional classroom, where students are passive learners and instructors transfer their knowledge on the basis of lecturing still dominates today's classroom. This teaching method has limited effectiveness in helping students develop high-level thinking skills (Miles et al., 2005). Games and simulation represent active and experiential techniques that have been used to broaden the spectrum of traditional teaching techniques and to improve the effectiveness of students' learning (Smetana, 2012). Games and simulations enable effective situated learning by simulating environments or scenarios that cannot be directly presented in a traditional classroom (Okkola and Kassi, 2012; Akilli, 2011). As experiential simulate real world situations, they promote dynamic participation and fast learning which stimulate deeper learning and comprehension of subject complexity to maximize the transfer and application of academic knowledge into specific situations (Deshpande and Huang, 2011; Mayo, 2007).

Games and simulations are experiential exercises where learners apply their knowledge and skills as well as use strategies in the execution of their assigned roles. In general, games are competitive exercises in which the objective is to win, and players apply relevant knowledge in an effort to advance in the exercise and win (Zapalska et al., 2010). In a simulation that illustrates a case study of a particular social or physical reality, the players assume roles with well-defined responsibilities and constraints. These open-ended situations with many interacting variables can take different directions, depending on the actions and reactions of the participants. Students' progress is monitored and assessed; feedback is given to the learners, who consider outcomes as important in their learning process. As games enable students to take decisions and manage the process, instructors are required to switch into a facilitator's role, instead of just being an observer, thus refurbishing the traditional, linear approach of content creation and delivery. Instructors act as facilitators of the experience and are responsible for ensuring that learners claim accountability for their assigned actions (Prusak, 2004). The paper demonstrates the Manufacturing Simulation that integrates the learning community with principles of communication, shared knowledge, and responsibility. The goal for engineering students is to take active roles in order to address the issues or problems that arise in the production situation and to experience the process of decision making in a business environment. The learning objective of the Manufacturing Simulation is to provide students with the opportunity to make production allocation decisions in a competitive market and to examine the strategies in which information can be used in the production allocation decision. Since no requirement is made for teams to provide or share any information, the teams may create their own business strategies and ethical system. The development of the ethical skills is also an important objective of the simulation.

The simulation involves few rounds where each of the rounds is independent and can be played relatively quickly as the market structure has been simplified. The Manufacturing Simulation as an experiential learning activity which allows engineering students to practice communication and negotiation skills as well as to develop business strategies and an understanding of ethics. The active learning environment allows individual teams to make decisions based on imperfect information and with conflicting goals. The simulation permits players to control certain aspects of the information flow relevant to the market, and players create their own business and ethical strategies in a complicated and uncertain business environment.

Literature Review

Games have been used to educate students for many years across all majors (Gee, 2007; Michael and Chen, 2005; Prensky, 2007). They are based on problem-based learning (Savin-Baden and Major, 2004), experiential education (Dewey, 1938/1963; Kolb, 1984), and decision science (Raser, 1969). Studies support effectiveness of simulations and games for teaching and learning (Feinstein, 2001; Hartman and Gommer, 2019). Educational research documents that simulations and games develop critical thinking, increase student motivation (Akilli, 2011), enhance team learning and collaboration, stimulate information retention (Gestwiski and Morris, 2012), improve the integration of concepts (Squire and Jenkins, 2003), and develop critical thinking and problem-solving skills (Michael, 2006). Plass (et al., 2015) argues that the use of experiential learning with games and simulations within the specific context and domain of engineering education increases motivation, student engagement, and adaptability as students benefit from their learning experiences. Frein and Ott (2015) argue that simulations in a virtual environment have been studied in various education domains when time, inaccessibility to the physical environment, safety, cost, or other barriers prevent the physical event from taking place.

Savin-Baden and Major (2004) elaborate on how gamers are successful because of development of social skills, problem solving, collaborative and teamwork skills. Similarly, Zapalska et al. (2010) claims that games improve practical reasoning skills, develop higher levels of continuing motivation, and reduce training time and instructor load. Literature (Miles, at al. 2005) highlights communication, business ethics, teamwork, leadership, and creativity. Similarly, Ellington (2001) documents that games and simulation support development of strategic thinking, planning, group decision-making as well as communication and negotiating skills. However, the relationship between learning experiences and development of business strategies such as communication and ethical standards in simulations and games still remains not fully discussed in the educational engineering education.

The simulation draws upon a rich heritage of games and simulations to demonstrate a complex interaction of production decisions as well as the role of communication and ethics within a specific business engineering environment (Gibson, 2003). Deshpande and Huang (2011) argue that simulation game-based education is the problem-based learning where both experiential learning, collaborative, active, and learner centric approaches are utilized to create an effective learning environment.

Research on games and experiential learning has proven that games and simulations are important pedagogical tools recommended for classroom use. Games and simulations reach students regardless of learning style or how quickly they are able to learn new information and concepts. Deshpande and Huang, (2011), argued that games are a method of organized experiential learning that incorporates an element of fun in the learning process while Le´ger (2006) and Williams (1980) stressed that games help connecting theory and practice to foster students' understanding of the subject as well help students to change their attitudinal positions when designed in accordance with theory. Games and simulations open up dynamic participation, develop innovative ideas and concepts (Petranek, 1994) and guide students in understanding concepts and provide students a holistic working knowledge of the subject (Kharma, 2001). Crown (2001) stressed that games and simulations deliver immediate feedback during learning process while Torres and Macedo (2000) recommended games and simulations as they provide students an opportunity to face the consequences of the results of the decisions taken or process applied. They make repetition and drill on a specific topic more enjoyable, thus allowing the student to develop proficiency in a given area. Moreover, they offer increasing range of difficulty to challenge the students as they develop to a more advanced level of comprehension (Crown, 2001) and show greater retention over time than the traditional classroom instruction (Rendal et al., 1992).

The first approach to games and simulations as an educational tool in engineering is the "Construction Management Game" (Au et al., 1969) which simulates the bidding process in the construction industry. This model has inspired a variety of research efforts in the area of games and simulations: CONSTRUCTO (Halpin and Woodhead, 1970), AROUSAL (Ndekugri and Lansley, 1992), SuperBid (AbouRizk, 1992), Parade of Trades (Choo and Tommelein, 1999), Simphony (Hajjar and AbouRizk, 1999), STRATEGY (McCabe et al., 2000), The Construction Marketing Game (Bichot, 2001), VIRCON (Jaafari et al., 2001), ER (Nassar, 2002), and the Virtual Coach (Rojas and Mukherjee, 2005). These efforts provide stepping-stones towards creating interactive, participatory, and contextually rich educational environments in construction engineering and management. Thus, using games and simulations to help students learn is not a completely new idea in the construction engineering and management education (Philpot, et al., 2003). Deshpande and Huang (2011) argue that as "… simulation games have promising applications in engineering education there is a need for a virtually integrated and comprehensive simulation game applications that will enable holistic understanding of a subject where the students can interrelate various concepts, understand the tradeoff involved, resource constraints, and their practical significance…" (page 408).

Keyt and Cadotte (1981) created a game that demonstrated the complex interaction of production decisions. This was a multi-period game that allowed groups to interact and introduced random factors determined by the roll of the dice. While comprehensive games have their place, it is often useful for the instructor to have an exercise that can be conducted in a single period (Brozik and Zapalska, 1997). In order to construct a single period exercise that is meaningful to the students, it is necessary to simplify the market structure and create environment that is intuitive and easy to comprehend (Cannon and Ternan, 1997). Additional benefit can be gained if an ethical dimension can be designed into the exercise (Scott, 2008; Gibson, 2003). The Manufacturing simulation, presented in this paper, was designed to meet all these requirements. Each of the rounds is independent and can be played relatively quickly because the market structure has been simplified. This market, however, can be understood by the students, and student interaction creates a unique ethical environment.

The benefits of the manufacturing simulation, presented in this paper, arrive from an active experience that students obtain while participating in this active learning. This simulation engages students in discovery processes, promotes learning through reflection on the personal learning experience, facilitates social interaction, language acquisition and communication skills as well as develops ethical aptitudes that are critical in engineering profession.

Goals of Games and Simulations: teaching facts, skills, and behaviors

The main purpose for using a simulation or game is to bring as much reality into the classroom as possible. They can be used effectively to teach concepts such as human relations, economic principles, decision-making skills, and problem solving. While it is important to consider what goes into the game, it is critical to consider what comes out of the game. Games can be used to provide three distinct outcomes: to teach facts, to teach skills, and to teach behaviors. It is also possible to have outcomes that combine one or more of these three characteristics. The desired outcome is the driving factor in the design of the game.

The Manufacturing game is fact oriented with the desired outcome for students focused on learning how businesses operate. By repeating the exercises, students can be drawn into the learning process. These types of exercises do benefit from repetition since the students that did not win the first game are provided with an incentive to study and win subsequent games. The Manufacturing game is also a skill-oriented game as it strives to teach or improve a specific, task-oriented business strategies and behavior. In this game, once the participants understand the technique and hence specific strategies that are expected to be learned, there is little use in repeating the exercise under the same initial conditions. However, modifying the boundary conditions of the game can create a new learning opportunity, but this would actually be a different game. The Manufacturing game is also a behavior-oriented game as it allows the participants to learn how to act and react in specific situations, the best example would be learning business ethics skills. The game was also used to teach participants how to communicate more effectively to accomplish desired goals. While there is possibly to advance some skill component (like business negotiation and debates) in these exercises, the overall aim of the exercise is broader than mastering a single skill.

A simulation or game may be designed to teach facts, skills, or behaviors. While each desired outcome is sufficient in itself to be the reason to design a simulation or game, combinations can be achieved to address complex issues and environments. A properly designed exercise will address only those outcomes associated with the learning goal. The Manufacturing game is an example of a fact/ skill/ behavior game/ simulation exercise that involves three primary goals. Participants need to learn the facts about the relevant manufacturing company, develop the skills and behaviors associated to business environment so that negotiation, strategic and tactical thinking skills are learned and developed. This type of simulation is fairly complex in structure and may have to be repeated to get the maximum benefit.

Moreover, The Manufacturing game has been arranged using the Kolb's experiential learning model (1984) with four major stages, including active experimentation, concrete experience, reflective observation, and abstract conceptualization. The Kolb's model is presented in Figure 1. This paper adopted the Kolb's learning process as this model views learning as an integrative process with each stage mutually supportive of and automatically leading to the next stage. This model allows students to enter the cycle at any stage and follow it through its logical sequence. Effective learning occurs when learners experience or process through all four stages of the Kolb's model.

Figure 2 presents how the model of Kolb's experiential learning has been incorporated into three rounds of experiential learning process, allowing knowledge to be continuously derived from and tested out in the experiences throughout three rounds. At each round of the Kolb's model, students discover, experience, and advance the concepts and knowledge as well as specific skills through conscious experimentation and practice. The three rounds that are implemented allow students to develop, discover, experience and advance specific skills and learn the concepts thoroughly and methodologically. This experiential learning process continues throughout three repetitive rounds allowing students to advance understanding and knowledge of specific concepts, and most importantly kills, and behaviors; including: planning, negotiation, communication, strategic

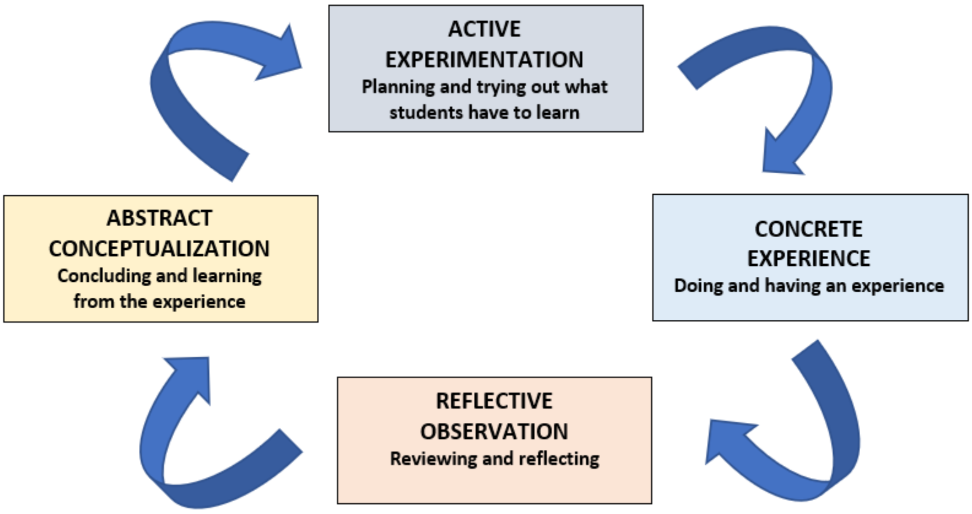


Figure 1. Kolb Model of Learning

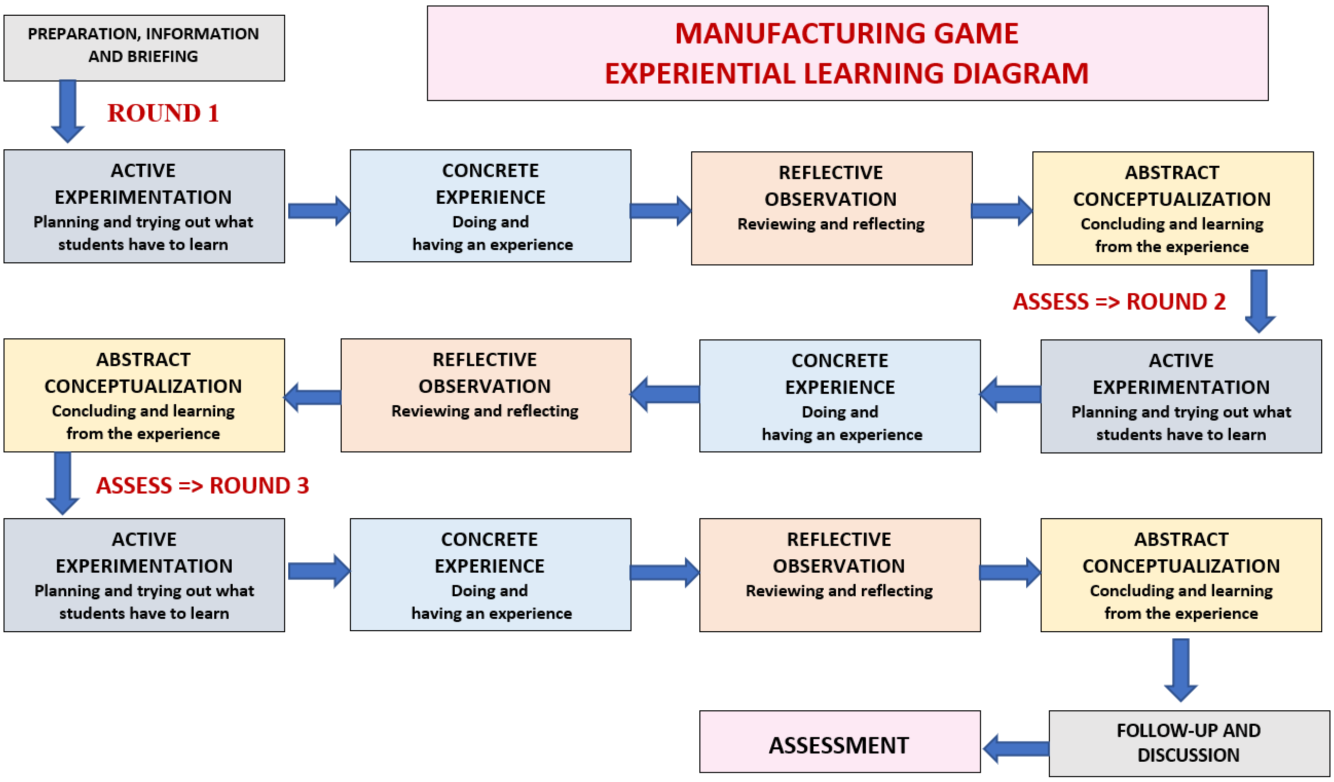


Figure 2. Experiential Learning and Manufacturing Game Diagram with Three Rounds Conducting The Manufacturing Simulation

thinking, teamwork, problem solving, and business ethics.

The Manufacturing simulation is designed to be played without computer assistance. While some instructors might choose to create spreadsheets that duplicate the Instructor's Forms, it is not necessary to do so. All required calculations can be done easily in the classroom. Each round of the simulation takes about 10 to 20 minutes. Rounds can be repeated as necessary until students demonstrate the required level of mastery. It is not necessary to complete the entire exercise in one session. The rounds are sequenced in a manner that allows the instructor to choose those that best match the class material. The periodic scheduling of the rounds may actually prove more effective in some classes since it would allow students multiple exercises to break the flow of the normal class routine and give them time to assimilate what they learn in each particular exercise.

The Manufacturing simulation is designed to be played by four teams. Team sizes can vary between three and five members. We do not recommend more than five members per team as communication is lost and inefficiencies arrive. For larger classes it is recommended that eight teams be formed and that they alternate playing the rounds. The mechanics of recording the results of each round can become complex when more than four teams are present. The teams should be formed at least one class session prior to playing the game by whatever protocol the instructor chooses. The simulation is composed of several rounds, each designed to illustrate a specific dimension of decision making and the information flows associated with it. The format creates a rich enough environment that factors like group dynamics and market ethics can be examined. The areas explored in each round are:

Preparation, Information and Briefing Stage (Learning Objective: Facts)

Each management team is given a Team Information Packet (Appendix A), which describes exactly how the simulation is played. This permits each team to use the time between classes to meet to discuss the facts of the game, and possibly determine an initial strategy. The Team Information Packet contains all relevant information about the simulation and Tally Sheets to facilitate score keeping. The Instructor's Forms (Appendix B) include the Master Tally Sheet and other schedules needed by the instructor. At this stage, the players are being informed that they are going to act in a competitive market. Thus, at that stage, students learn or discover facts of the game. Further, each student will act with other members of the team and represent its business firm. All teams are expected to make resource allocation decisions for their firms while competing with other firms. The teams learn that each firm has different production capacity and production costs structure. Information concerning the competition and, therefore, a market structure is incomplete and inaccurate. Moreover, knowledge of the market demand for various products is not available to the players. The teams must make decisions concerning production allocation and product mix for their firms in an uncertain environment

The Competitive Communications simulation creates a controlled, uncertain environment for decision-making. Players are formed into teams that must decide what is best for their firm, in the presence of other teams trying to do what is best for their firms. Opportunities are created for collaboration and collusion, though teams are not required to communicate any information with any other party. The interactions of the teams develop a business ethic that can also be examined.

Concrete Experience – Round 1 (Doing and Having an Experience)

After facts and foundations of the game and simulation are understood, the Concrete Experience starts with Round 1 that allows the teams to experience more than the facts. Players must understand, evaluate, analyze and solve the problem to make business decisions under market ethics. In this round, teams are experiencing decision making in isolation. All groups have the same cost structure and production capacity, so there are no inherent differences in market power. No communication is allowed between teams, and the results of the round are random. Sometimes all groups will choose to pursue a middle-of-the-road strategy, and each group gets roughly the same score. The purpose of this round is to experience and demonstrate the disadvantages of decision making without information. After team-made decisions concerning output mix without communicating with any of the other teams, they are expected to use the Tally Sheet to record their decisions. Once all teams have announced their production decisions, the sales price of each item will be calculated, and the teams can calculate the total profits earned. At this stage, students start developing communication and critical thinking skills through observation and application of several concepts they learned in class.

Reflective Observation – Round 1 (Reviewing and Reflecting on the Experience)

After the total profits are calculated, the teams reflect and evaluate their decisions regarding resource allocation and actions they took. At that stage, all teams are allowed to discuss among the group members their decisions and how their decisions affected the results. At this stage student are using analysis, evaluation, and, and problem solving, and the groups' reflection on decisions allows the groups to be prepared for Round 2.

Concrete Experience – Round 2 (Doing and Having an Experience)

In Round 2 the groups are allowed to communicate and share information with the other teams. They can collude if they decide or do anything they wish. Given the experience gained from the Round 1, the players are ready to make decisions while using the advantages of information and use it for personal gain. No requirement is made that the information exchanged must be accurate. The players are allowed to lie if they choose as it is the beginning of the development of a market ethical system. The types of information teams decide to share, and its accuracy is up to each team. Teams, however, are under no compulsion to share information nor will there be any direct sanction for sharing inaccurate information. Teams will be required to use the Tally Sheet to record their decisions. Once all teams have announced their production decisions, the sales price of each item will be calculated, and teams will be able to calculate the total profits earned.

Reflective Observation – Round 2 (Reviewing and Reflecting on the Experience)

After the teams calculated the profits, they are expected to reflect and evaluate their decisions regarding resource allocation in Round 2. Teams are also expected to compare their decisions in Round 2 and contrast with decisions they made in Round 1. A discussion among the group members on their decisions allows them to reflect on their decisions and how those decisions affected their results. This reflective observation prepares teams for Round 3.

Concrete Experience – Round 3 (Doing and Having an Experience)

In Round 3, production capacity, manufacturing costs, and market demand remain unchanged. In this round, an "Industry Expert" will be available to all firms for advice. During the first part of the round each firm develops a plan based upon available resources, and the Expert visits each team to review their individual strategies.

Reflective Observation – Round 3 (Reviewing and Reflecting on the Experience)

Teams are then allowed a short period of time to communicate with each other and exchange whatever information they see fit. Teams work alone to develop their final market plans. The Expert visits the teams to answer any questions concerning overall industry trends that may be beneficial in the planning process. After the Expert has visited all teams, the teams can share information with the other teams. There is no requirement that the Expert convey accurate information. There is also no requirement concerning the accuracy of the information to share. Teams experience the impact of the information accuracy on their allocation and profit results.

After teams had the opportunity to share information, the Expert will visit each team and answer questions concerning market conditions. The players will use the Tally Sheets to record their decisions. Once all teams have announced their production decisions, the sales price of each item will be calculated, and the total profits earned can be calculated.

Abstract Conceptualization (Concluding and Learning from the Experience) and Active Experimentation (Planning and Trying out what was Learned)

It is informative to foster a discussion concerning each team's decisions at each round and share their opinion of the relative honesty of the other teams and their impact on resource allocation and profits. There are definitely different opinions of exactly what happened, and it can be shown that concepts like truth and fairness can be relative or misunderstood. The cycle of experiential learn continues until facts, skills, and behaviors are learned and fully advanced. There are three rounds that allow for all those learning objectives to be completed.

Follow-up and Debriefing

After every round, students are expected to summarize their results and general debrief session is being held to make sure that the facts and certain decision-making skills are properly made. The final discussion that takes place round 3 is completed provides an overview of the problems of decision making in a dynamic environment. There should be time dedicated for a class discussion that takes place after each round concerning the success of each team and the market conditions that led to that success. Some of this discussion should focus on what information was available, the utility of this information, and the validity of the information. Discussion also should focus on the value of specific market and product characteristics, the development of the information flow, and the behavior of market participants.

Assessment of the Manufacturing Simulation

Post-simulation activity assessment can address two general purposes. One is to examine the dynamics of the simulation exercises and the overall results. The other purpose is to reinforce the process of knowledge acquisition as well as the realism of the performance feedback. Therefore, post-simulation activity is essential to fulfill the educational value of the simulation. Post-simulation activities can include post-simulation surveys, post-simulation debriefings, and group discussions. As a result of these activities, it may also be necessary for the instructor to carry out follow-up teaching. In order to fully realize learning effectiveness, a post-simulation survey may be administered to each individual learner immediately after the game or simulation. This survey may ask general and specific questions. General questions are usually centered in student perceptions of exercises. Specific questions tend to require learners to think analytically about their decisions and their consequences.

Assessment, evaluation, and reflection are important steps for experiential learning. Instructors can take advantage of group analyses and debriefing sessions. In these activities, learners can be asked to describe the events that occurred, account for their actions, and discuss the merits of alternative strategies to solve the problems encountered. These post-simulation activities may generate a cognitive conflict within a group of learners because students may challenge the perceptions and decisions made by others during the simulation. As a result of this cognitive conflict, learners begin to reorganize their ways of thinking about a particular set of events and how various perspectives contribute to a more complex understanding of the processes and projects they will work on throughout their engineering careers.

During assessment process, the instructor asks students to comment on their learning process and how this experiential learning contributed to students' learning and mastering concepts and specific skills. Some of the general comments included:

"I did enjoy this active learning as I was able to experience and make decisions to win the game. It was fun to work in teams and compete against other teams. This competition increased motivation and provided an opportunity to see how real business operates and how incentives matter."

"It was fun to play with other students while making business decision in this Manufacturing game. What I enjoyed the most was the experience, and opportunity to revised decision as the game was repetitive and allowed me to revise my decisions and improve my decision making."

"This game was very educational and even it was difficult its repetitive nature allowed me and my team to think and see how our decision making could be improved to end up with better solutions. It was also great to see how impact of other teams impacted our decisions and how difficult markets can be. My teammate and I learned that teamwork is critical in competitive environment. The game was great to play as we never do anything like this in other classes. "

Conclusions

Simulation and game-based learning approaches aim to imitate a system, entity, phenomenon, or process. They attempt to represent or predict aspects of the behavior of the problem or issue being studied. Simulation and games allow experiments to be conducted within a fictitious situation to show the real behaviors and outcomes of possible conditions. As the skills required of today's engineers are a combination of technical knowledge and management skills the Manufacturing simulation is designed to give students the opportunity to experience decision making in a dynamic setting. The firms may or may not have similar information. The information received may or may not be accurate. Expert intervention may be honest or misleading. The Manufacturing simulation shows the importance of information in decision making. Players are required to establish a market ethical system, and honesty may or may not be a part of that system. In short, the simulation allows students to experience the real world in the classroom.

Traditional education settings provide students with less opportunity for active participation and engagement due to the fear of failure. Therefore, learners need to be exposed to real-like situations in a safe place to practice various professional skills. The Manufacturing simulation presented in this paper contributes to the engineering educational literature. As a simulation-based learning environment is created, engineering students become responsible for their own learning. The role of instructor is radically different from the one in a traditional classroom environment and instructor must supervise individual work and provide help, support, and encouragement to individuals when required.

The role of instructor in our simulation is of a coach; the role of an instructor is to organize the simulation and facilitators of the learner's learning experience. The instructor has responsibility for conveying the Manufacturing simulation as a pedagogical activity. This paper has emphasized that the success of simulations as educational tools depends on the efforts performed to integrate them with other pedagogical activities. In order to enhance the effectiveness of such tools, this paper has also described activities that instructors can use before, during, and after applying games and simulations.

The Manufacturing simulation gives the instructor the ability to tailor the learning experience to classroom needs. The game can be conducted in a concentrated or extended manner, and it is only necessary to use those modules appropriate to the class. Besides the exercise in decision making and information processing, the game creates a common body of experience that is rich enough to foster discussion concerning business ethics from an experiential angle.

The Manufacturing simulation can be used in many ways and thus provides the instructor with another approach to effective learning. During simulations students learn from mistakes and thereby gain a deeper understanding of the learning objective rather than a learner who avoids mistakes by chance without understanding concepts. In addition, our simulation offers students problem solving exercises where concepts are embedded in the context promoting learning within the nexus of the activity.

References

AbouRizk, S., and Sawhney, A. (1994). Simulation and gaming in construction engineering education. ASEE/C2E2 /C2EI Conference, Edmonton, Alberta, Canada, American Society for Engineering Education.

Akilli, G. K. (2011). Games and simulations: A new approach in education. Gaming and Simulations: Concepts, Methodologies, Tools and Applications, ed. Information Resources Management Association, USA, 150-167.

Au, T., Bostleman, R. L., and Parti, E. (1969). Construction management game-deterministic model. ASCE Journal of Construction Division, 95, 25-38.

Bichot, T. (2001). The Construction Marketing Game. Masters Thesis, Bradley University, Peoria, Illinois.

Brozik and Zapalska (1997) "The Market Game: Interactive Learning Through Market Simulation." Developments in Business Simulation and Experiential Learning, Volume 24, 1997, 166-171.

Choo, H. J., and Tommelein, I. D. (1999). Parade of trades: A computer game for understanding variability and dependence. Technical Report 99-1, Construction Engineering and Management Program, Civil and Environmental Engineering Department, University of California, Berkeley, CA, September.

Cannon and Ternan (1997) “Contextually-Anchored Business Simulations.” Developments in Business Simulation and Experiential Learning, Volume 24, 1997, 322-328.
Crown, S. W. (2001). Improving visualization skills of engineering graphics students using simple JavaScript web-based games, Journal of Engineering Education. 90), 347-355.
Dewey, J. (1938/1963). Experience and Education. New York: Collier Books.
Deshpande, A. A., and Huang, S. H. (2011). Simulation games in engineering education: A state-of-the-art review. Computer Applications in Engineering Education, 19(3), 399-410.
Ellington, H. (2001) ‘Using Games Simulations and Case Studies to Develop Key Skills’, in M. Boyle and Y. Smith (eds) Simulation and Gaming Research Yearbook, SAGSET.
Feinstein, A. H. (2001) ‘An Assessment of the Effectiveness of Simulation as an Instructional System’, Journal of Hospitality and Tourism Research 25(4): 421–43.
Frein, L., & Ott, M. (2015). A literature review on immersive virtual reality in education: State of the art and perspectives. eLearning and Software for Education (eLSE), April 23-24, Bucharest, Romania.
Gee, J. P. (2007). What Video Games Have to Teach Us About Learning and Literacy, New York: Palgrave MacMillan.
Gibson, K. (2003). Games students play: Incorporating the prisoner’s dilemma in teaching business ethics. Journal of Business Ethics, 48(1), 53-64.
Gestwicki, P., & Morris, R. (2012). Social Studies Education Game Development as an Undergraduate Immersive Learning Experience. In M. Cruz-Cunha (Ed.), Handbook of Research on Serious Games as Educational, Business and Research Tools (pp. 838-858). Hershey, PA: Information Science Reference. doi:10.4018/978-1-4666-0149-9.ch043
Hajjar, D., and AbouRizk, S. (1999). Simphony: An environment for building special purpose construction simulation tools. Proceedings of the 1999 Winter Simulation Conference, December, 998-1006.
Halpin, D.W., and Woodhead, R.W. (1970). CONSTRUCTO - A computerized construction management game. Construction Research Series, No.14, Department of Civil Engineering, University of Illinois, Urbana, IL, December.
Hartmann, A., Gommer, L.: To play or not to play: on the motivational effects of games in engineering education. European Journal of Engineering Education. (2019)
Jaafari, A., Manivong, K., and Chaaya, M. (2001). VIRCON: Interactive system for teaching construction management. Journal of Construction Engineering and Management, 127(1), 66–75.
Keyt and Cadotte (1981) “CHIPS: A Marketing Channels Management Game.” Developments in Business Simulation and Experiential Learning, Volume 8, 1981, 242-246.
Kharma, N. L. Caro, and V. Venkatesh, (2001). MagicBlocks: A construction kit for learning digital logic, Computer Application Engineering Education. 13, 35-46.
Kolb, D. A. (1984). Experiential Learning: Experience as the Source of Learning and Development. Englewood. Cliffs: Prentice-Hall.
Le´ger. P.M. (2006). Using a simulation game approach to teach ERP concepts, HEC Montre´al, Groupe de recherche en syste´mes d’information, Montre´al.
Mayo, M. J. (2007). Games for Science and Engineering Education. Communications of the ACM, 50(7), 31-35.
McCabe, B. Y., Ching, K. S., & Savio, R. (2000). STRATEGY: A Construction simulation environment. Proceedings of the ASCE Construction Congress VI, Orlando, FL, February, 115-120.
Michael, J. (2006). Where’s the evidence that active learning works? Advances in Physiology Education, 30(4), 159–167.
Michael, D., and Chen, S. (2005). Serious Games: Games That Educate, Train, and Inform, Boston: Thomson Course Technology PTR.
Miles, M., Melton, D., Ridges, M. and Harrell, C. (2005), "The Benefits of Experiential Learning in Manufacturing Education", Journal of Engineering Technology, Vol. 22, No. 1, pp. 24-28.
Nassar, K. (2002). Simulation gaming in construction: ER, the equipment replacement game. Journal of Construction Education. 7(1), 16-30.
Ndekugri, I. Y., and Lansley, P. (1992). Role of simulation in construction management. Building Research and Information, 20 (2), 109-115.
Okkola, T. and Kässi, T. (2012), "Designing an Industrial Management Curriculum, Overcoming Obstacles", Int. Journal of Industrial Engineering and Management, Vol. 3, No. 2, pp. 67-74.
Petranek, C. (1994). Amaturation in experiential learning: Principles of simulation and gaming, Simulat Gaming: International Journal. 25, 513-522.
Philpot, T. A., Hubing, N., Hall, R. H., Flori, R. E., Oglesby, D. B., & Yellamraju, V. (2003). Games as teaching tools in engineering mechanics courses. In Proceedings of the American Society of Engineering Education.
Plass, J., Homer, B., Kinzer, C. (2015). Foundations of game-based learning. Educational Psychology. 50(4), 258–283
Prensky, M. (2007). Digital Game-Based Learning. St. Paul, Minnesota: Paragon House Publishers.
Prusak, K. (2004), "Problem Definition and Problem Solving in Lean Manufacturing Environment", in Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition, pp. 195-206.
Randel, J. M., B. A. Morris, C. D. Wetzel, and B. V. Whitehill. (1992). The effectiveness of games for educational purposes: A review of recent research, Simulation Gaming 23, 261-276.
Raser, J. R. (1969). Simulation and Society: An Exploration of Scientific Gaming. Boston: Allyn and Bacon Inc.
Rojas, E., and Mukherjee, A. (2005). A general-purpose situational simulation environment for construction education. Journal of Construction Engineering and Management, ASCE, 131 (3), 319-329.
Savin-Baden, M., and Major, C. H. (2004). Foundations of Problem-Based Learning, Maidenhead: The Society for Research into Higher Learning & Open University Press.
Scott, J.A. (2008). Simulations as a Source of Learning: Using StarPower to teach Ethical Leadership and Management. Journal of Leadership Education. 7 (1).140-149.
Smetana, L. K., and Bell, R. L. (2012). Computer simulations to support science instruction and learning: A critical review of the literature. International Journal of Science Education, 34(9), 1337-1370.
Squire, K., & Jenkins, H. (2003). Harnessing the power of games in education. Insight, 3(1), 5-33.
Thavikulwat (1988) “Simulating Demand in an Independent-Across-Firms Management Game.” Developments in Business Simulation and Experiential Learning, Volume 15, 1988, 183-187.
Torres, M. and J. Macedo, (2000). Learning sustainable development with a new simulation game, Simulation Gaming. 31, 119-126.
Williams, R. H. (1980). Attitude change and simulation games: The ability of a simulation game to change attitudes when structured in accordance with either the cognitive dissonance or incentive models of attitude change, Simulation Games, 11, 177-196.
Zapalska, A., Brozik, D., and D. Rudd. (2010). “Development of Active Learning with Simulations and Games”. US-China Education Review, A 2, 164-169.

APPENDIX A:

TEAM INFORMATION PACKET

COMPETITIVE MARKETS AND COMMUNICATIONS

THE SCENARIO:
Your firm is one of several international manufacturers of electrical generation and transmission equipment. Due to the recent power shortages in the United States and other parts of the world, there has been an increased demand for the products you manufacture. As managers of your firm, it is your responsibility to plan production and sales to meet the demands of a competitive market in order to maximize the wealth of your shareholders.

THE COMPETITION:
You have three major competitors that are roughly the same size and that produce equipment with the same capabilities as your firm's products. These four firms form an industry subgroup:

Northern Wind Energy
Eastern Solar Equipment
Southern Hydrodynamics Systems
Western Hybrid Components

These firms compete directly on the following items:

Frequency Modulators (FM)
Voltage Transformers (VT)
Power Regulators (PR)

From the point of view of potential customers, your firm's products are interchangeable with those of any of your competitors. For example, a frequency modulator from any of the four firms is considered to be identical in capability. (Note: A frequency modulator is not interchangeable with a voltage transformer or power regulator.)

DOMICILE:
None of the four firms is based in the United States even though the US is a major market for these products. Since the firms are not bound by US laws, there is no legal restriction (anti-trust laws) against sharing information between firms, but there is likewise no requirement that information be shared. The amount of information exchanged between firms is decided by the managers of the firm, as is the accuracy of that information. Even though these firms are based in different countries, since their products are sold in the US, all cost and price information is quoted in US dollars.

THE DECISION REQUIREMENT:
In each round of the game, you will be required to decide how many of each type of product to sell in order to maximize the wealth of your individual shareholders. There are two specific production factors that you must consider in making your product allocation.

1. The quantity of each item you plan to produce must be a multiple of ten. For example, if you have 100 items to allocate, you can choose to produce 10 FM, 20 VT, and 70 PR or any other combination that adds to 100 units as long as each individual allocation is a multiple of ten. You cannot choose to produce 3 FM, 5 VT, and 92 PR. Should you choose to allocate production quantities that are not multiples of ten, the number that you choose will be rounded down to the nearest multiple of ten; this will result in your team losing production and thus losing revenues.

2. In order to maintain the ability to offer a product in the next round, you must offer at least 10 of that product in the preceding round. This requirement assures that the equipment and personnel needed for production will be available. For example, if in Round 1 you choose not to produce any FM, then you will not be allowed to offer any FM in Round 2. You will be allowed to offer FM in Round 3 should you wish to do so. The reason that you must skip a round after not offering a product is that it will take you this much time to restart the production process.

THE GAME STRUCTURE:
There are multiple rounds to the game, each round examining a different aspect of competition and information flow. Cost and price structures may change between rounds, and it is your responsibility to make decisions in light of the changing market conditions. During each round, you will have approximately 10 minutes to decide your production mix.

MANAGERIAL INCENTIVES:
In order to receive credit for this part of the course, you will be required to submit a paper documenting the game and your performance during the game. This paper will be graded on a 100-point scale. The members of the winning team in each round of the game will receive a 5-point bonus which will be added to the grade on the paper. For example, if a single team is able to win three rounds, it would be possible for the members of that team to receive a score of 115 points

on the 100-point paper (if the paper itself does not merit a score of 100, the bonus points will still be added to whatever score the paper receives). In each round, the members of the second-place team will receive a bonus of 3 points, and the members of the third-place team will receive a bonus of 1 point.

In the event of a two-way tie in any round, the combined points will be split equally between the two tying teams. If the tie involves more than two teams, that is, if three or more teams receive the same score in a specific round, no bonus points will be awarded to those teams for that round.

COMPETITIVE MARKETS PRODUCT DEMAND CURVES

An industry marketing board has surveyed potential buyers of electrical equipment. Based on the information from this survey, the following demand schedules have been constructed for the products your firm manufactures. Due to market conditions, the minimum price for any product is $100,000 regardless of the quantity available in the market.

COMPETITIVE MARKETS AND COMMUNICATIONS

Manufacturing Capacity: Each firm has the capacity to produce a total of 150 units. Due to the manufacturing process, it takes the same amount of time and materials for each product. The firm can therefore produce various combinations of finished products, like 150 FM and 0 VT and 0 PR, or 50 FM and 50 VT and 50 PR, or any other combination that totals150 units.

Manufacturing Costs: The cost to produce a single unit (FM, VT, or PR) is $300,000.

Product Demand: See Product Demand Curve graphs.

ROUND 1

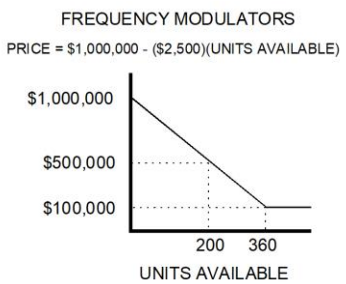
Make your decision concerning your output mix without communicating with any of the other teams. Use the Tally Sheet o record your decision. Once all teams have announced their production decisions, the sales price of each item will be calculated, and you can calculate the total profits earned.

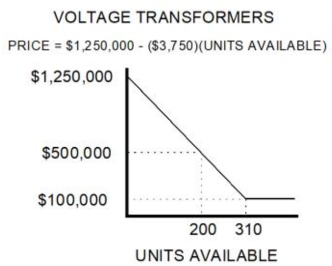
ROUND 2

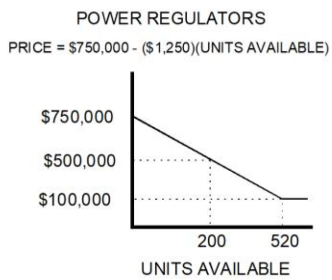
Prior to making the output mix decision, you may share information with the other teams. The type of information you share, and its accuracy, is up to you. You are under no compulsion to share information, nor will there be any direct sanction for sharing inaccurate information. Use the Tally Sheet to record your decision. Once all teams have announced their production decisions, the sales price of each item will be calculated, and you can calculate the total profits earned.

ROUND 3

An Industry Expert will be available to assist you should you wish. While you are making your initial plans, the Expert will visit your team and ask questions. It is your choice whether or not the information you provide is accurate. After the Expert has visited all teams, the teams can share information with the other teams. There is no requirement concerning the accuracy of the information you share. After you have had the opportunity to share information, the Expert will visit each team and answer questions concerning market conditions. Use the Tally Sheet to record your decision. Once all teams have announced their production decisions, the sales price of each item will be calculated, and you can calculate the total profits earned.







APPENDIX B: INSTRUCTOR'S FORMS

PRODUCTION ALLOCATION
ROUND 1

	FM	VT	PR	Total units
North				150
East				150
South				150
West				150
Total				

ROUND 2

	FM	VT	PR	Total units
North				150
East				150
South				150
West				150
Total				

ROUND 3

	FM	VT	PR	Total units
North				150
East				150
South				150
West				150
Total				

ROUND 1

		FM	VT	PR	
North	# UNITS				
	PRICE/UNIT				
	COST/UNIT	$300,000	$300,000	$300,000	
	PROFIT/UNIT				TOTAL PROFIT
	PROFIT				
East	# UNITS				
	PRICE/UNIT				
	COST/UNIT	$300,000	$300,000	$300,000	
	PROFIT/UNIT				TOTAL PROFIT
	PROFIT				
South	# UNITS				
	PRICE/UNIT				
	COST/UNIT	$300,000	$300,000	$300,000	
	PROFIT/UNIT				TOTAL PROFIT
	PROFIT				
West	# UNITS				
	PRICE/UNIT				
	COST/UNIT	$300,000	$300,000	$300,000	
	PROFIT/UNIT				TOTAL PROFIT
	PROFIT				

ROUND 2

		FM	VT	PR	
North	# UNITS				
	PRICE/UNIT				
	COST/UNIT	$300,000	$300,000	$300,000	
	PROFIT/UNIT				TOTAL PROFIT
	PROFIT				
East	# UNITS				
	PRICE/UNIT				
	COST/UNIT	$300,000	$300,000	$300,000	
	PROFIT/UNIT				TOTAL PROFIT
	PROFIT				
South	# UNITS				
	PRICE/UNIT				
	COST/UNIT	$300,000	$300,000	$300,000	
	PROFIT/UNIT				TOTAL PROFIT
	PROFIT				
West	# UNITS				
	PRICE/UNIT				
	COST/UNIT	$300,000	$300,000	$300,000	
	PROFIT/UNIT				TOTAL PROFIT
	PROFIT				

Team Name/Members:

ROUND 1

Product	FM	VT	PR	
Sales Price per Unit				
Cost per Unit	$300,000	$300,000	$300,000	
Profit per Unit				Total Units Sold
Units Sold				150
Total Profit per Product				

Grand Total Profit

ROUND 2

Product	FM	VT	PR	
Sales Price per Unit				
Cost per Unit	$300,000	$300,000	$300,000	
Profit per Unit				Total Units Sold
Units Sold				150
Total Profit per Product				

Grand Total Profit

ROUND 3

Product	FM	VT	PR	
Sales Price per Unit				
Cost per Unit	$300,000	$300,000	$300,000	
Profit per Unit				Total Units Sold
Units Sold				
Total Profit per Product				

Grand Total Profit

ROUND 3

		FM	VT	PR	
North	# UNITS				
	PRICE/UNIT				
	COST/UNIT	$300,000	$300,000	$300,000	
	PROFIT/UNIT				TOTAL PROFIT
	PROFIT				
East	# UNITS				
	PRICE/UNIT				
	COST/UNIT	$300,000	$300,000	$300,000	
	PROFIT/UNIT				TOTAL PROFIT
	PROFIT				
South	# UNITS				
	PRICE/UNIT				
	COST/UNIT	$300,000	$300,000	$300,000	
	PROFIT/UNIT				TOTAL PROFIT
	PROFIT				
West	# UNITS				
	PRICE/UNIT				
	COST/UNIT	$300,000	$300,000	$300,000	
	PROFIT/UNIT				TOTAL PROFIT
	PROFIT				

UNIT PRICES

# UNITS	VT	FM	PR
0	1,250,000	1,000,000	750,000
10	1,212,500	975,000	737,500
20	1,175,000	950,000	725,000
30	1,137,500	925,000	712,500
40	1,100,000	900,000	700,000
50	1,062,500	875,000	687,500
60	1,025,000	850,000	675,000
70	987,500	825,000	662,500
80	950,000	800,000	650,000
90	912,500	775,000	637,500
100	875,000	750,000	625,000
110	837,500	725,000	612,500
120	800,000	700,000	600,000
130	762,500	675,000	587,500
140	725,000	650,000	575,000
150	687,500	625,000	562,500
160	650,000	600,000	550,000
170	612,500	575,000	537,500
180	575,000	550,000	525,000
190	537,500	525,000	512,500
200	500,000	500,000	500,000
210	462,500	475,000	487,500
220	425,000	450,000	475,000
230	387,500	425,000	462,500
240	350,000	400,000	450,000
250	312,500	375,000	437,500
260	275,000	350,000	425,000
270	237,500	325,000	412,500
280	200,000	300,000	400,000
290	162,500	275,000	387,500
300	125,000	250,000	375,000
310	*100,000*	225,000	362,500
320	*100,000*	200,000	350,000
330	*100,000*	175,000	337,500
340	*100,000*	150,000	325,000
350	*100,000*	125,000	312,500
360	*100,000*	*100,000*	300,000
370	*100,000*	*100,000*	287,500
380	*100,000*	*100,000*	275,000
390	*100,000*	*100,000*	262,500
400	*100,000*	*100,000*	250,000

Assessment on Learning Management Systems for Open and Distance Learning of Engineering Courses

Article history
Received
24 October 2021
Received in revised form
18 November 2021
Accepted
20 November 2021
Published online
30 November 2021

Raudhah Othman[a], Siti Nur Mariani Mohd Yunos[a], Muhd Nazrul Hisham Zainal Alam[b]*
[a]Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia.
[b]School of Chemical & Energy Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia.
**nazrulhisham@utm.my*

Abstract
Engineering education in higher learning institute faces new challenges due to the rise of COVID-19 cases whereby classes have to be conducted online. In this regards, the use of learning management systems (LMS) are imperative for open and distance learning (ODL). The aim of this paper is to assess ODL using such LMS platform. Study was conducted in Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia where it involved a total of 51 academic staff. A quantitative method using online questionnaire was applied to evaluate main preferences of LMS for ODL, main purposes of LMS and issues arises from using such LMS platform. Results show that a variety of LMS has been utilized to support the ODL and majority of the academician showed positive feedback on the usefulness of such LMS. The only main concerns from the educators are plagiarism from the students that could create doubts and none trustworthy results on their performances. Otherwise, LMS is indeed an essential platform for ODL and must be encouraged to all educators such that it can be further improved and continuously utilized in the future.

Keywords: Online education; open and distance learning; learning management systems; engineering education. .

Introduction

The continuing spread of COVID-19 disease has affected and changed the landscape of higher education atmosphere. Due to this pandemic, in class lectures and/or face-to-face education is no longer an option as it will only increase the risk of COVID-19 infection. Moreover, in some countries (including Malaysia), the government has imposed a nationwide lockdown or Movement Control Order (MCO) where it limited the operation of many sectors – this include education. Engineering courses in higher learning institute suffered critically from this situation (Lubiński and Tama, 2021). Globally, teaching and learning activities must now be implemented virtually where many regarded it as the open and distance learning (ODL) education. ODL is the current trend in education as opposed to the conventional face-to-face lectures.

Since the spread of COVID-19 which began in early 2020, various types of Learning Management Systems (LMS), has been developed to support teaching and learning activities associated to ODL. LMS is generally referred to a web-based content management systems (or software) that enables educators to manage, plan, share notes, and conduct a variety of learning activities such as lecturing, quizzes, exam, etc. in an online medium (Aldiab et al., 2019) and thus, ideally suited for ODL purposes. Utilization of LMS for ODL is heavily relies on technology particularly electronic devices namely mobile phone, computer, and/or tablet as a medium of communication between lecturers and students. ODL can be conducted through various ways such as video conferencing, open online course, hybrid learning, computers based and fixed time online course where all can be executed via LMS (Chung, 2013). In one hand, the synchronous ODL can be conducted via video conference and chatroom and it provides direct interaction between the students and lecturers. On the other hand, asynchronous ODL provides indirect interaction as it happens not in real time and more flexible as student have options to study the materials provided by the lecturers independently at their own time and pace.

While some may have adapted to this abrupt change but many has raised concerns on two major aspects. Firstly, is on the readiness and acceptance of the faculty members as well as the students on such ODL environment. Secondly, on the effectiveness of the deliverables of lectures through online (internet) communication via LMS particularly on the development of important student skill set (the cognitive, psychomotor and affective domains). Delivering a face-to-face lectures in engineering courses is a challenging task. Often students have issues understanding complex theory and lecturers do need to go to the certain extent to provide a satisfactory explanation for it. Indeed, the use of LMS offers many options for the educators in conducting

ODL but can LMS be sufficiently applied in ODL to provide students and lecturers the same satisfaction as the traditional lecturing environment.

Clearly, utilization of LMS for ODL in engineering courses requires continuous assessment. Therefore, in present paper, assessment was conducted to highlight the following questions:

1) What are the most preferred LMS for ODL in engineering courses?
2) What are the main purposes of LMS in ODL?
3) What are the issues faced by lecturers in using LMS for ODL?

The study was conducted in Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia (UTHM). A questionnaire-based survey were created to get input for the study where in involved all academic staff of the faculty. Results attained from the survey conducted were discussed in details. Additionally, the paper also includes a brief review on previous studies.

Literature review

At the early stage of worldwide movement to online learning during pandemic, many studies have been conducted to assess ODL readiness among students (Chung et al., 2020; Ismail et al., 2020; Mathew & Chung, 2020) and the challenges faced by lecturers in implementing ODL (Irfan et al., 2020; Simamora et al., 2020; Simanjuntak & Panjaitan, 2021). Selvanathan et al. (2020) have highlighted that there are still many room for improvement in the online learning and teaching, particularly in terms of the quality of the interaction and instruction delivered to the students. In another study, Musa et al. (2020) suggest that one of the key elements to make ODL effective is student's motivation and this will also lead to student's performance.

Despite some concerns over typical issues found in LMS namely unfriendly interface, glitches, inability to link to third party tools, etc. (Irfan et al., 2020), LMS has grown in popularity to support the execution of ODL. The LMS allows lecturers to manage their classes and performing administrative tasks which include providing online class materials, conducting discussions and assessments, task evaluation and others online activities (Saidi et al., 2021). A study on the student readiness towards integration of LMS into their learning indicates that students who were computer literate were more ready to engage in LMS compared to those who are computer phobia (Fashina & Adisa, 2020).

In terms of infrastructure, Ismail et al. (2020) mention that reliable network infrastructure is important to ensure the delivery of the online learning is not interrupted and the quality is maintained. Therefore, it is crucial for the universities to increase their server bandwidth to support online teaching and learning through LMS.

There are many choices of free and paid LMSs to choose from such as Google Classroom, Edmodo, Moodle, Schoology and university's e-learning portals such as Blackboard, uFuture and Spectrum. While the freely available LMS can be adopted by any educators, some universities also have developed their own platform. However, further improvement in the university's LMS platform is highly needed to have efficient and effective adoption of this system (Alshira et al., 2021).

Meanwhile, an extensive review on the use of free web-based Google Classroom during the spread of COVID-19 has been given by Okmawati (2020). A study conducted by Irfan et al. (2020) at 3 universities in Indonesia suggests that Google Classroom, followed by Edmodo, are the most adopted LMS in teaching and learning as they are easier to use compared to the available LMS on campus. The university's LMS is found to be less attractive to lecturers since the functions are limited. Similarly, Saidi et al. (2021) shows that the most popular LMS among lecturers and students at public and private higher learning institutions in Malaysia is also Google Classroom, and this is followed by the university's very own LMS. In general, both studies indicated that lecturers and students showed positive perception on the use of Google Classroom for ODL. Since UTHM has its own LMS, it is within this perspective that this study aims to investigate Faculty of Mechanical and Manufacturing Engineering academic staffs' perspective and preference on the various LMS as a platform on ODL, particularly in conducting online assessments.

Methodology

In this study, a quantitative approach was implemented through the use of online questionnaire. The questionnaire has a total of 13 questions that was partly adopted from Ismail et al. (2020) and Aldiab et al. (2019) and is divided into three categories namely Section A, B and C. Section A of the questions was structured to capture the demographic information of the respondents. This include the duration of their working experience and the type of program (undergraduate and/or post graduate) they have been assigned on in the last three (3) semesters. In Section B, multiple choices questions were formed to gather the respondent's feedback on the learning management systems (LMS) for open and distance learning (ODL). These include their preferred communication method and live meeting platform with students for ODL. Questions about purposes of using LMS for ODL are also included in this section. There are 8 choices (questions) and respondents are allowed to select more than one answer (i.e. anywhere from 1 up to 8 choices given). The last section (Section C) comprises the ranking type questions about utilization of the most preferred LMS platform for assessment in ODL which included continuous assessments and evaluation of final examinations. Respondents were required to compare each options in the order of preferences with 3 is the most preferred method, 2 neutral and 1 is the least preferred method.

Section C also comprises question about issues on the use of LMS for assessment of ODL. These issues are common in LMS and respondents were required to choose which one of these issues are the most pressing ones for them in using LMS for ODL.

Total participants (respondents) for this study is 51 where respondents are academicians (i.e. lecturers and professors) in Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia (UTHM). The questionnaire was administered using a Google form platform and was sent as links to the respondents via WhatsApp. Respondents were required to complete each questions on the survey given within the period of one week. Data attained were assessed and discussed in the following section.

Results and Discussion

This section presents and discusses the results of the survey, which consists of lecturer preferences of LMS for ODL, purposes in using LMS for ODL among the lecturers, and issues faced by lecturers in the use of LMS for assessment of ODL.

Preferences of LMS for ODL

Figure 1 shows the distribution of the lecturers in Faculty of Mechanical and Manufacturing Engineering, UTHM according to their working experience as academician and the type of programs they have been assigned on in the last three (3) semesters. The survey revealed that out of 51 respondents, 54% of the faculty members have at least 15 years of working experience between them, about 36% have experience as academician for 6 to 15 years and 10% of the respondents have less than 5 year working experience as lecturers. Most of the faculty members i.e. up to 62% of them were assigned to teach undergraduate courses where else about 38% have been assigned to handle courses in both postgraduate and undergraduate programs. The results attained are in agreement with the fact that experience members of the faculty are obviously professors who has vast experience in lecturing and has also been trusted to handle advance engineering course for the postgraduate program.

Nevertheless due to COVID-9 pandemic, lecturers are forced to use technological platform such as LMS to facilitate their teaching and learning activities. This completely change the education paradigm. In the traditional lecturing system, often skilled professors are popular amongst the students as education and evaluation are highly depending on the educators experience and knowledge. However, in virtual environment i.e. online based education, this may not be case. Quality of teaching is now depending on the educator capacity to apply various online tools in their teaching and learning activities. Junior faculty can easily become the experts and preferences in ODL simply because he/her readiness to accept the change and started exploring a variety of LMS platform. Indeed, junior faculty maybe a fast learner when it comes to adaptation of new technological tools but experience professors are a great speaker and motivator which is also valuable in online learning medium. Clearly, apart from continuous technical support from help desk, mixture of junior members and experience staff in a department/faculty holds a pivotal role in this matter in order to ensure a smooth transition from the traditional lectures environment into ODL regardless of faculty member background.

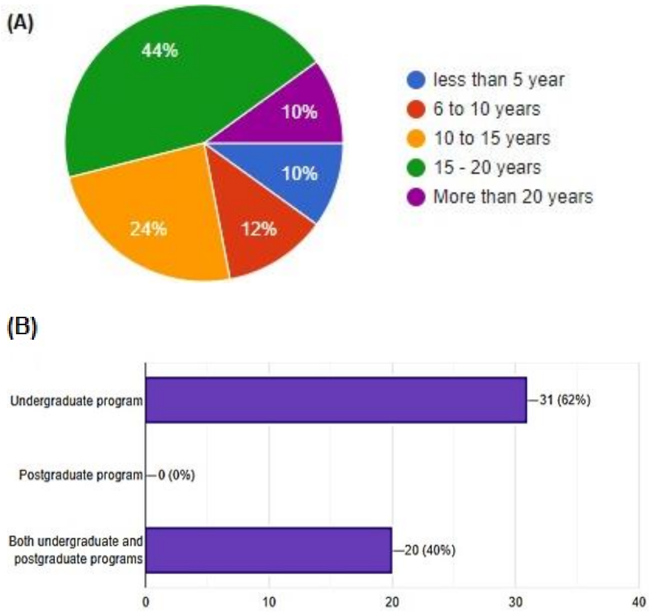


Figure 1. (a) Respondents working experience as academician and (b) the type of programs they have been assigned on.

Figure 2 presents the information about respondent's preferences on the type of communication method and live meeting session for ODL. As shown in Figure 2(a), majority i.e. approximately 90% of the academic staff preferred to use WhatsApp medium for online communication with the students where else nearly 10% of the academician preferred to engage the students using Telegram platform. This is clearly an obvious choice for the lecturers as WhatsApp medium is among the most popular mobile messenger application in the world (Yusoff et al., 2021). Plus no additional training is required as both lecturers and students are already exposed to such technology in their daily online communications. Furthermore, such an online mobile application also enable lecturers to create specific group for any academic courses for information sharing which is very beneficial especially to initiate the first lecture in the beginning of every semester. Contrary to emails or Facebook, WhatsApp medium helps lecturers to engage in active communication with the students at any time i.e. within the boundary of academician working hours and thus, keep them focus and motivated in enduring ODL throughout the semester.

Based on the results presented in Figure 2(b), although Zoom and Microsoft Teams are among the best video conferencing tools, many of the faculty members (i.e. 92.2% out of the total 51 respondents) preferred to utilize Google Meet as their platform for live meeting (online lectures) with the students. Google Meet is the main preference probably due to several reasons. Firstly, many of the lecturers is already using Google as their main internet search engine and live streaming (or lecturing) via Google Meet is sort of embedded in their mind settings. Secondly, Google Meet is also secure and easy to use whereby no installer is needed and academician can initiate online lecturers directly from the internet browsers with only couple of steps. Finally, Google also couples various attractive online services for teaching and learning such as google classroom, google drive, etc. with can be couple with online meetings via Google Meet. This sort of features truly attracts the academician in managing their ODL activities (Uziak et al., 2018).

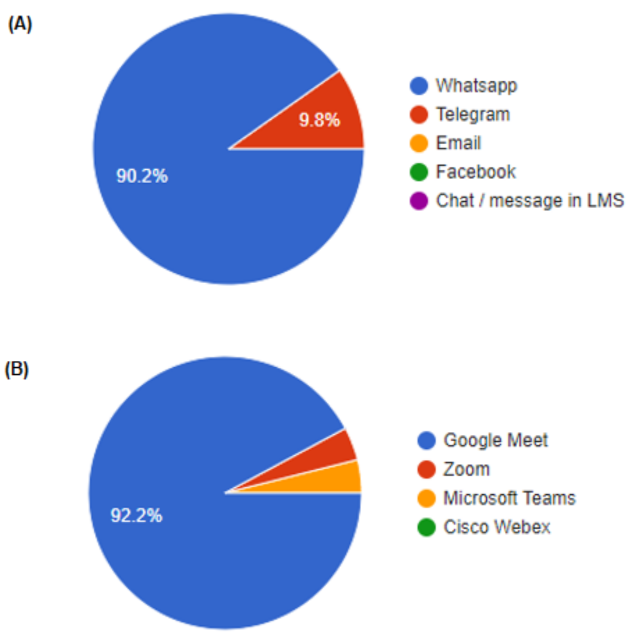


Figure 2. Respondent's preferences on (a) communication method and (b) live meeting platform for ODL.

Figure 3 illustrates the respondent's preferences on type of LMS for their online teaching and learning activities. It was found that 54.9% of the respondents choose to work with UTHM very own LMS namely Author UTHM, 35.3% preferred Google Classroom medium, about 4% utilized Microsoft Teams and only a small number amongst the academician (i.e. between 3-5%) would opted for gaming based LMS such as Kahoot, Moodle, and Edmundo for their online lecturing medium. It is common nowadays that every higher learning institute has their very own LMS. This is essential for assigning courses (teaching loads) to lecturers and a main platform for lecturers to share course materials with the students. In UTHM, such LMS for teaching and learning activities are called Author UTHM. Author UTHM has been used by academic staff even before the pandemic. Its usefulness becomes even more pronounced due to the pandemic since everything has to be done online. Additionally, new features have been added into Author UTHM platform to allow lecturers to form and/or conduct their own blended learning strategy (Sanudin et al., 2019). So, it was to be expected that many of our academician still relying mainly on Author UTHM for ODL as they have indeed familiarized themselves with such LMS platform. Alternatively, Google Classroom is also a good LMS platform for ODL. Some of our faculty members have extensively utilized its usefulness and was used as complimentary in their online lecturers to support what is lacking in Author UTHM. The gaming based LMS is clearly still in exploratory phase for our staff and not many are keen to create such gaming environment in their online teaching and learning activities. Plus, it is not so straight forward to execute and it requires proper planning and structure (Zainal Alam, 2020). Nevertheless, the variety tools used for teaching and learning indicated the level of creativity of the lecturers in our department in conducting their ODL. It has also been reported that the use of various online teaching tools are essential for student cognitive development in their education (Zainal Alam and Zakaria, 2021).

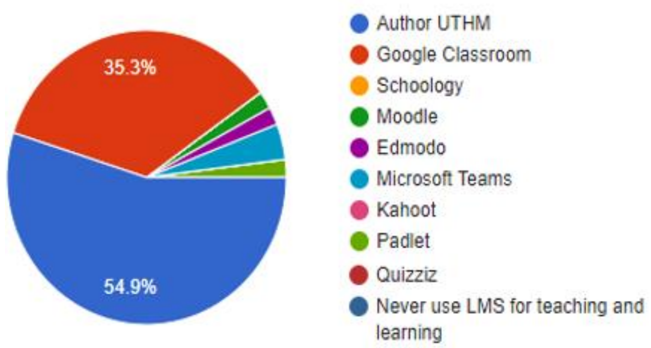


Figure 3. Respondent's preferences on LMS for online teaching and learning activities.

Main Purposes of LMS for ODL

The data in Figure 4 shows the responses of the faculty members on the main purposes in using LMS platform for ODL activities. In this particular questionnaire, participants are allowed to select any of the options provided in the survey. Most LMS platform contains various administrative tools and a variety of interactive features to support online learning (Al-Hunaiyyan et al., 2020; Kraleva et al., 2019). However, in accordance to the results in Figure 4, out of 8 of the items asked, majority i.e. more than 90% of the academician in our faculty utilized LMS mainly for administrative purposes. These include sharing of course information (98%), uploading of course materials (96.1%), and creating links to assign and retrieval of student assignments (94.1%). Obviously, it is important to share the details of the taught course to the students to make sure the students are aware of what they are going to learn, what they need to achieve at the end of the course from the course learning outcomes and the assessments to be carried out and how they are evaluated.

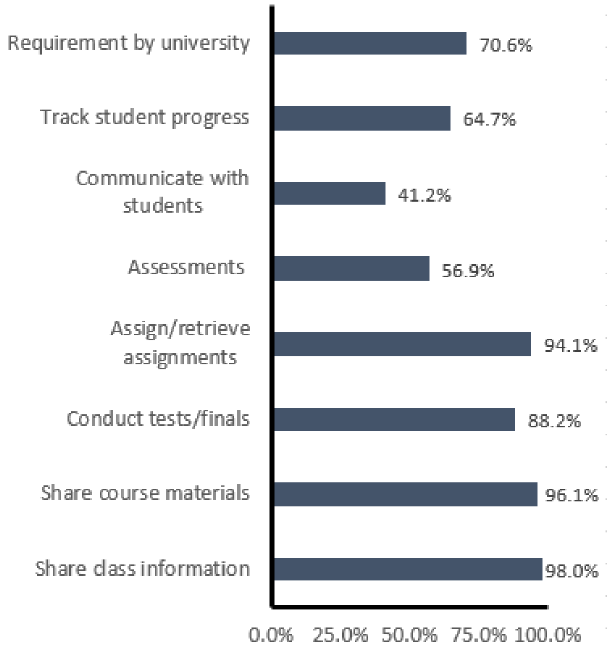


Figure 4. Purposes of using LMS in open and distance learning (ODL) activities.

Conducting tests and carrying out final examinations using LMS also rank amongst the top choices by the respondents (88.1%). This is due to the fact that through LMS, tests/finals can be implemented either through synchronous or a synchronous approach which indeed very handy for the academician for ODL. There is an attractive feature in LMS platform where it enables one to automatically add up student cumulative course work marks (Kraleva et al., 2019). This is truly a useful feature for lecturers to track student progress throughout the semester but our data indicated that only few (~64.7%) exploited this function. Lack of training and unaware about such feature could probably be the reason why many didn't use LMS for that purpose. Some i.e. about 70.6% of the academician believed that they are only using LMS simply to comply with the university job requirement. Moreover, results in Figure 4 also indicated that LMS is probably not the best medium in assessment (56.9%) and communication with students (41.2%) for our academician. Communication is probably best executed via WhatsApp medium as it is easy and student questions can be attended to instantaneously. As for assessment especially student assignment and tests, it is most likely because lecturers still prefer to do it manually. Having it done online is not so straight forward and also because in higher learning engineering courses many of the examination questions are subjective that requires a thorough assessment on every solution/step provided. Results of this study is in agreement with some of the published works (Al-Hunaiyyan et al., 2020) where LMS is mainly used for administration of course work while interactive features such as chatroom, forum discussion, etc. are rarely applied.

Issues associated to LMS for assessment of ODL

Assessment is a procedure of obtaining information on the student achievement/knowledge based on what they have learnt or gained in the course they are attending. Generally, there are two types of assessment; namely formative and summative. Formative assessment is an on-going assessment during the lesson merely to evaluate how well students are learning the course materials. On the contrary, summative assessment is a measure of student understanding in the end of the course – typically this is done through the final examination (Singh and Thurman, 2019). Both are equally important elements in handling ODL as it measures the student progress and also as an indicator for lecturers to make any necessary changes in improving the student centred learning process they are implementing in the course. Creating such online assessment in ODL is indeed a challenging task. It can either be a quick assessment via online quizzes (or tests), online polls, direct feedback and reflections, or through game-type activities of which all can be implemented using various LMS platform. Figure 5 presents the preferences of the participants on the type of LMS for assessment of ODL.

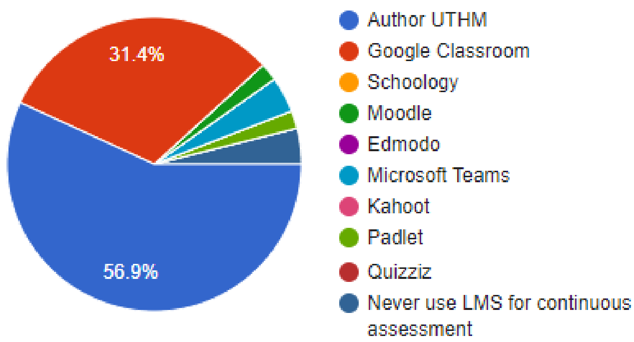


Figure 5. Preferences on type of LMS for assessment of ODL.

According to the data, similar trend as in preferences for teaching and learning activities is observed. Nearly two-third i.e. about 56.9% of our academic staff preferred to use Author UTHM medium for assessment. Utilization of Google Classroom ranks second at 31.4% and followed by Microsoft Teams. It is presumed that the choices were made based on the type of assessment that lecturers usually applied in their ODL session i.e. online quizzes and tests. Both approach are relatively easy to implement on line and suitable to measure learning results regardless the size of the class. Other medium such as Kahoot, Moodie, Edmundo, etc. are less favourable. Although such LMS is considered 'fun' and not 'test like' endeavours, lecturers do need to explore it first (probably on their own) and design it accordingly to get a proper feedback from the students. Else, students would merely be playing games rather than providing info on their level of understanding. Furthermore, lack of training and support from the institute could also be another reason that hinders lecturers from applying such game-based LMS in their ODL session.

Our argument is confirmed through the choices made by our academician on the type of online assessment they would implement in ODL using LMS (Figure 6). In this questionnaire, respondents were required to select the type online assessment of their own preferences for ODL using LMS platform. They were required to rank their choices in accordance to most preferred (rank 3), neutral/uncertain (rank 2) and least preferred (rank 1). It was found that majority (i.e. >35 staff out of 51) of the academician in our faculty preferred to use LMS only for various types of assessments. These include online test, individual and/or group assignment and projects. Moreover, these assessments are mostly open-ended type of evaluation where it is aimed to test student understanding on their theoretical knowledge. Open-ended questions are much more suitable for engineering courses in higher learning as it allows lecturers to design each questions according to the learning objectives they wanted to achieve (most likely student cognitive abilities).

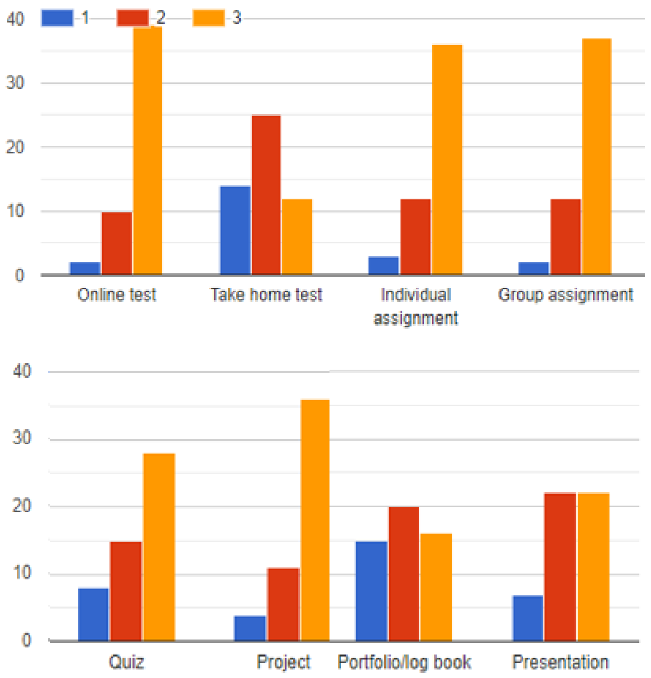


Figure 6. Respondent's choices on the type of online assessment for ODL using LMS platform.

Figure 7 highlights the respondent's perception on issues in using LMS for assessment of their ODL activities. From the results, inability to detect plagiarism or academic dishonesty during tests/finals ranked first with 35.3%. Academic dishonesty is generally refer to cheating or exam frauds which is something that is rather difficult to detect in online environment. Students could easily copied information from the internet or exchange theirs answers with their classmates unnoticeable. In this scenario, lecturers could only give the students the benefit of the doubt and constantly remind them about academic integrities. Alternatively, lecturers could prepare different version of the same tests and carry out vetting procedure of the test questions to check for its suitability for online examination environment. Moreover, lecturers should ask everyone to turn on their web cameras and set a time limit in answering each questions given such that student would focus more on finding the solution to the problems given rather than to find ways to share it with their friends. Finally, in order to check academic integrity within answers submitted by the students, lecturers could use turnitin software where such software enabled lecturers to assess similarities of each test answers submitted.

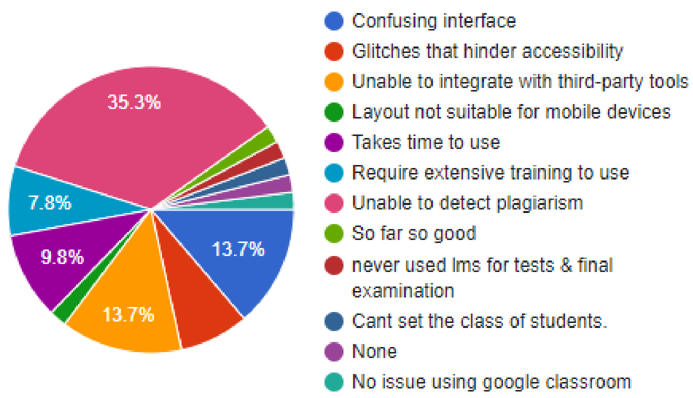


Figure 7. Issues experienced by respondents in using LMS for assessment.

Another pressing issue is inability to integrate with third-part tools (compatibility issues) and confusing LMS interface where both ranked second with 13.7%. Compatibility issues would in fact limited the type of LMS functions for the lecturers. Furthermore, if technical support are not provided at times of need, lecturers would probably give up and stop using such LMS medium. Confusing interface is also troublesome especially if one could not locate the right icon on the dashboard and/or if the LMS contains many broken links. This usually happen to LMS with poor interface and indeed demoralized lecturers. Other main concerns associated to the use of LMS for assessment of ODL activities as experienced by our participants include the need for extensive trainings (7.8%) and the amount of time that one needed to spend while using LMS (9.8%). It is suspected that lack of practice (or motivation) and support from expert users amongst the faculty members could probably be the main reason for this. This issue can be overcome through a proper training programs and continuous support from the management to all academician about the use of LMS for ODL sessions.

Conclusion

The paper aimed at evaluating preferred learning management system (LMS) for open and distance learning (ODL) of engineering courses. The study was conducted in Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia (UTHM) using online questionnaires. Based on the results of the survey, it can be concluded that many has already familiarized with such LMS platform for open and distance learning where majority collectively agreed that LMS is mainly used for course administration purposes. These include exchange/sharing or course materials and for continuous assessment of student progress. Participants reported that the main issue in using LMS for ODL is inability to detect plagiarism during online assessment. Other concerns are not as critical and are solvable through series of training programs. Encouraging lecturers to continuously explore and actively use LMS in their ODL activities is indeed essential as it is considered as part of the effort in improving lecturers skill set in online teaching.

Acknowledgement

We would like to express our gratitude and thanks to all academic staff of Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia (UTHM) for their dedication and participation in this study.

References

Aldiab, A., Chowdhury, H., Kootsookos, A., Alam, F., Allhibi, H. 2019. Utilization of Learning Management Systems (LMSs) in higher education system: A case review for Saudi Arabia. Energy Procedia, vol 160. 731-737.

Al-Hunaiyyan, H., Al-Sharhan, S., Aljahri, R. 2020. Prospect and Challenges of Learning Management Systems in Higher Education. International Journal of Advance Computer Science and Applications. vol 11(12). 73-79.

Alshira, M., Al-omari, M., Igried, B. 2021. Usability Evaluation of Learning Management Systems (LMS) based on User Experience. Turkish Journal of Computer and Mathematics Education (TURCOMAT). vol 12(11). 6431–6441.

Chung, C. 2013. Web-based Learning Management System Considerations for Higher Education. Learning and Performance Quarterly. vol 1(4). 24–37.

Chung, E., Noor, N. M., Vloreen Nity Mathew. 2020. Are you ready? an assessment of online learning readiness among university students. International Journal of Academic Research in Progressive Education and Development. vol *9*(1).301–317.

Fashina, T., Adisa, O. I. 2020. Perception and Readiness Towards Integration of Learning Management System (LMS) Into Open and Distance Education. In Paper Knowledge . Toward a Media History of Documents (Issue March, 12–26).

Irfan, M., Kusumaningrum, B., Yulia, Y., Widodo, S. A. 2020. Challenges During the Pandemic: Use of E-Learning in Mathematics Learning in Higher Education. Infinity Journal, vol 9(2). 147-158.

Ismail, N. S., Bakar, N. M. A., Wafa, S. W. 2020. Online Learning Challenges during Pandemic COVID-19 in Malaysian Higher Learning Institution. Universal Journal of Educational Research. vol 8(12). 7151–7159.

Kraleva, R., Sabani, M., Kralev, V. 2019. An Analysis of Some Learning Management Systems. International Journal on Advanced Science, Engineering and Information Technology, vol 9. No. 4 ISSN: 2088-5334, 2019.

Lubiński, K., D.K. Tama, 2021. The observed effects of distance learning on curriculum implementation in management and business studies. Procedia Computer Science. vol 192. 2540-2549.

Mathew, V. N., Chung, E. 2020. University Students' Perspectives on Open and Distance Learning (ODL) Implementation Amidst COVID-19. Asian Journal of University Education. vol 16(4). 152–160.

Musa, A. H., Rosle, A. N., Baharuddin, F. N., Ibrahim, S. S. 2020. The Effectiveness of Online Distance Learning (ODL) Approach in University: A Respond of Covid-19 Pandemic Crisis. International Journal of Academic Research in Business and Social Sciences. vol 10(9). 1069–1076.

Okmawati, M. 2020. The Use of Google Classroom during Pandemic. Journal of English Language Teaching. vol*9*(2), 438. https://doi.org/ 10.24036/ jelt.v9i2.109293.

Saidi, R. M., Sharip, A. A., Abd Rahim, N. Z., Zulkifli, Z. A., Md Zain, S. M. 2021. Evaluating Students' Preferences of Open and Distance Learning (ODL) Tools. Procedia Computer Science. vol 179. 955–961.

Sanudin, R., Sahdan, M.Z., MOhd Tawil, S.N., Ruslan S.H. 2019. Assessment using e-learning Platform in UTHM. 1st International Malaysian Educational Technology Convention. 149-156.

Selvanathan, M., Hussin, N. A. M., Azazi, N. A. N. 2020. Students learning experiences during COVID-19: Work from home period in Malaysian Higher Learning Institutions. Teaching Public Administration. https://doi.org/10.1177/0144739420977900.

Simamora, R. M., De Fretes, D., Purba, E. D., Pasaribu, D. 2020. Practices, Challenges, and Prospects of Online Learning during Covid-19 Pandemic in Higher Education: Lecturer Perspectives. Studies in Learning and Teaching. vol 1(3). 185–208.

Simanjuntak, D. C., Panjaitan, N. B. 2021. The inevitable surge of online learning through the lens of English education lecturers during the unprecedented times. Journal on English as a Foreign Language. vol 11(2). 358–380.

Singh, V., Thurman, A. 2019. How Many Ways Can We Define Online Learning? A Systematic Literature Review of Definitions of Online Learning (1988-2018). American Journal of Distance Education. vol 33(4). 289-306.

Uziak, J., Oladiran, T., Lorencowicz, E., Becker, K. 2018. Students' and Instructor's Perspective on the use of Blackboard Platform for Delivering an Engineering Course. The Electronic Journal of e-Learning. vol 16(1). 1-15.

Yusoff, S. A. M., Kadar, R., Mohamad, W. A. W., Mydin, A., & Abdullah, M. H. 2021. The Impact of WhatsApp as an Instructional Tool for Online Distance Teaching and Learning (ODL). International Journal of Academic Research in Progressive Education and Development. vol 10(2). 585–595.

Zainal Alam, M.N.H. 2020. Arduino for Chemical Engineering Students via Game-based Learning. ASEAN Journal of Engineering Education. vol 4(1). 19-29.

Zainal Alam, M.N.H, Zakaria, Z.Y. 2021. Application of Computational Tools to support Cooperative Learning in Bioreactor Design Course. International Journal: Emerging Technologies in Learning. vol 16(15). 46-61.

Design Your Experiment (DYE) – Project-Based Learning in Fluid Mechanics Laboratory

Article history
Received
14 October 2021
Received in revised form
11 November 2021
Accepted
15 November 2021
Published online
30 November 2021

Jay Shah, Prachi Thareja*
Chemical Engineering, Indian Institute of Technology (IIT), Gandhinagar, India, 382355
**prachi@iitgn.ac.in*

Abstract
There is a need to implement an active and student-centered learning experience in the universities, which could help students expand their vision and better understand its application and concepts outside the classroom learning. This article discusses an approach of Design your experiment (DYE) project in the Fluid Mechanics laboratory to make the course more interesting for the students. We discuss various components involved in the DYE project and its learning outcomes. The reaction survey of 40 students collected through an online questionnaire shows that the DYE helps the students to enhance their fundamentals, improve their communication, leadership and team management skills.

Keywords: Fluid Mechanics; laboratory; project-based learning.

Introduction

This article discusses an active learning methodology in an engineering laboratory course for undergraduate Fluid Mechanics (FM). FM is a core subject in the engineering curriculum in several institutions around the world. The theory course of FM is generally taught in a more passive manner, where the students learn through the lectures delivered by the instructor. The assessment of the theoretical concepts is carried out with weekly quizzes, assignments and exams. However, engineers must have a practical knowledge about the subject they are studying. The theory course of FM is often considered challenging due to many complicated equations, which many students are not able to relate to its practical applications. Therefore, an FM laboratory course is included in the curriculum. FM laboratory courses help the students improve their understanding of the fundamentals studied in the classroom.

The goals of laboratory instruction in engineering education is discussed in an excellent paper by Feisel and Rosa (Feisel and Rosa, 2005). The authors claim that the role of instructional laboratories is not limited to instrumentation, lab scale models, data analysis, but also encompasses design, learning from failures, creativity, teamwork, communication and ethics in laboratory. These skills are not just confined to learnings in laboratories but are also valid in today's highly globalized employment scenarios. The engineers are expected to be technically competent along with their ability to apply the knowledge to the complex problems. Therefore, there is a need to include active learning modules where the students play a more dominant role than the instructor in laboratory courses.

Project based learning is a pedagogical approach of active learning. The engineering education has largely been taught with problem-based learning approach, which has traditionally been widespread in instruction in medicine (MILLS and JE, 2003). Mills and Treagust provide a very thorough overview of problem based and project-based learning in engineering education (MILLS and JE, 2003). The problem-based approach is centered on defining a problem and the students are required to research and acquire knowledge about the potential solutions to the problem. The project-based learning approach is focused on application and using the prior acquired knowledge. The two approaches are very similar, however there are few distinguishing features of project-based learning (1) projects typically require a longer time duration and may be performed in stages. (2) projects may be carried out along with theory courses (3) emphasis on experimentation (4) working in groups and collaboration (5) communication (Palmer and Hall, 2011) (Chua, Yang, and Leo, 2014).

Educators have implemented and reported the project based learning approach in FM instructional laboratories. Jack A Pulea, discuss a design-based FM laboratory, which encourages the students to learn beyond the traditional books and learn the concept of buoyancy and stability (Puleo Jack A., 2020). The method results in improving the hands-on experience for the students and developing their communication skills. A continuous project-based learning was implemented for hydraulic engineering students. The students were asked to start from develop a pipe network, which was then integrated with other courses during the whole duration of bachelors or masters degrees (Pérez-Sánchez and López-Jiménez, 2020). Another educator incorporated, creative assignment in FM lab in the form of development of thought problem, frugal lab, presentations and fun with fluids segment (Mandavgane, 2020).

To incorporate active learning in the FM laboratory course and motivate the students to study FM, an open-ended project, titled "Design your Own Experiment (DYE)" was introduced, where a group of students worked together and designed an experiment to understand the fundamental concepts of FM. In this paper, we describe the FM laboratory course and how the DYE project evolved over years of experience. DYE helps the students explore the subject outside the textbook and understand the real-life application of the concepts learned in the classroom. It also builds social skills, as students need to perform the experiments in groups, which helps improve peer to peer learning.

FM Laboratory and Theory Course

Theory Course

FM theory course is offered to the Mechanical, Chemical, Civil Engineering and Material Science departments in the fourth semester of the B.Tech. curriculum. The FM course covers the fundamental concepts of the velocity field, fluid statics, law of conservation of mass/ momentum/ energy, incompressible inviscid flow, external incompressible viscous flow, potential flow, dimensional analysis, flow in pipes, boundary layer theory, Reynold- Transport Theorem and Navier-Stokes Equation.

Structure of FM Laboratory

FM laboratory is a 2-credit course in which the students have 3 hrs/week session. The course is included in the same semester as the theory course for the Chemical Engineering department. The students are given the laboratory manual, short instructional videos which have the brief background of the theory behind the experiments. In addition, reference to additional reading from the textbook of Fox and McDonalds is also provided (Robert W. Fox, Alan T. McDonald, and John W. Mitchell, 2020). Laboratory experiments were conducted in groups of three to four students.

The component of the FM laboratory consists of:

1. Pre- lab reports and viva-voce
2. Conducting experiments in the lab
3. Analysis of experimental data acquired in the laboratory
4. Writing of in- lab reports
5. DYE project

The students are required to analyze the data collected from experiments during laboratory hours. The report writing is divided into two parts.

(a) **Pre-lab reports (40 pts)** - Students need to write a pre-lab report, which helps understand the experiment's theory and concept before the actual experiment. The pre-lab report includes, abstract (5pts) and introduction (35 pts) of the experiment. This report is to be submitted before the experiment.

(b) **In-lab reports (60 pts)** - This report needs to be submitted at the end of the laboratory session, and it consists of experimental procedure (20 pts), experimental observations, calculations, results (total 30 pts), discussion and conclusion (10 pts)

Overall, both the reports help students understand, analyze, and communicate the experiments performed in the laboratory.

The course is evaluated based on the following grading policy:

In-lab reports - 25%
Pre-lab reports - 20%
Pre-lab viva-voce - 15%
Mid semester exam - 20%
DYE Project -20%

Table 1 consists of the experiments that are conducted in the FM laboratory course. The experiments elucidate experimental hands-on working of theoretical concepts of viscosity, flow meters, friction in pipes and columns, and centrifugal pumps.

Table 1: List of the Experiments in FM lab

Serial Number	Experiment
1	Viscosity by Stokes law
2	Viscosity by Efflux time
3	Reynolds Experiment
4	Bernoulli's Theorem
5	Orifice meter/ Venturi meter
6	V-notch
7	Friction in a circular pipe
8	Friction in annulus/rectangular pipe
9	Equivalent length of pipe fittings
10	Friction in a packed column
11	Characteristics of the centrifugal pump

DYE project

The DYE project involves a group of students designing and demonstrating the experiments related to FM. The budget for each student group was fixed to encourage students to implement the project frugally. Students can design the experiment based on any peer-reviewed research papers or design the experiments based on the FM theory course's concepts, write a report, and present their work to the class. A team of three to four students were formed to conduct their project.

Timeline of DYE project

The DYE project was assigned to students at the beginning of the semester; however, the students started working on it after the mid-semester exams and were given six weeks to develop, design and present their work. In the first year of the "DYE project" execution, teams needed to submit the report and presentation at the end of the semester. In the subsequent years of its execution, the DYE project was executed in two stages. In the first stage, the teams prepared a project proposal, and they were given feedback on the development and improvement of the design. The second stage involved hands-on design and execution of the experiment, report writing and presentation.

Role of the instructor in DYE project

The instructor's role is of a facilitator and a guide at various stages of the exercise. The students are required to present their initial proposal about the project to the instructor. The instructor ensures that the DYE is feasible in the laboratory with given resources and the time frame. The instructor does not provide the solution to the students, but instead points them to the relevant articles, textbooks which provide the technical background. The instructor also interfaces with the laboratory staff in case supplies are to be procured for the implementation of the DYE project.

Evaluation of DYE project

The DYE project was evaluated based on the presentation and report. The students were given the following instructions for presentation:

1) A maximum of 12-minute presentation. Every member must speak. Exceeding 12 minutes would lead to a penalty of 10 points.
2) Presentation would be judged on the originality of the experiment, introduction, analysis, and discussion of results.
3) Presentation should have conclusions slide and a slide highlighting the contributions of each member.

DYE Projects completed in FM lab course

The students' teams have worked on many innovative ideas for the DYE project. The groups worked on the fundamentals that were taught during the laboratory sessions. The list of the projects and its learning outcome is tabulated in Table 2.

Reaction Survey of DYE Project

After the completion of the FM laboratory course, an online questionnaire was sent to students for feedback on DYE projects. The students were asked to submit their opinions and the learning impact they had from the project.

Table 3 shows the questions in the survey along with the choice of responses. A score was attached to each response to quantitatively analyze the reaction survey. The questions reflect the learning outcomes from the DYE project. In this online survey, we received 40 responses from the students who took the course over the years.

Table 2: DYE Projects as part of FM lab course

Serial Number	Project Title	Learning Outcomes
1	Calculation of power consumed by centrifugal pump	Calculation of the head developed and power consumed by the pump.
2	Steady and unsteady discharge of a v-notch weir	Calculation of the coefficient of discharge V-notch for steady open-channel flow maintained using a centrifugal pump and calibrate flow rate with respect to Height
3	Verification of velocity profile for a closed laminar flow	Observation of the radial velocity profile for a fluid flowing through a circular pipe and verifying the relation with Navier Stokes Equation
4	The validity of the creep flow assumption	Investigate the creep flow of steel balls of different diameters under the influence of the wake of the steel balls of varying numbers dropped in the column of castor oil.
5	Determine the internal diameter of the pipe in a turbulent flow regime	Comparison of the experimental result of calculating the internal diameter of pipe using Colebrook's equation
6	To measure the coefficient of surface tension of a given fluid	Calculating the surface tension using a force balance
7	Rope coil effect	Experiments to study how the coils formed change as the height of the point of efflux varies.
8	Accelerating fluid	Experimental verification of the formula $\tan \theta = a/g$, when the fluid in the container has acceleration equal to 'a'.

9	Predictive capabilities of Bernoulli's Equation using efflux time	To understand the assumptions in the Bernoulli equation.
10	Hydraulic lift	Experiment to verify the Pascal law and understand it applications
11	Characteristics of centrifugal pump	To determine the performance characteristic of the pumps connected in series and parallel.
12	Centre of pressure on a submerged lane surface	Experimentally locate the center of pressure of a vertical, submerged plane surface.
13	Jet impact on flat and curved surfaces	Experimentally determine the force acting on the flat and curved surfaces with respect to the jet velocity.
14	Metacentric height of a floating body	Determining the metacentric height of a floating body and establishing a relation between the metacentric height and heel angle.
15	Head loss in circular pipe	Experiment to calculate minor head loss coefficient and determine the variation with Reynold Number
16	Comparative study of friction factor in annulus\rectangular\circular Pipe	Determine the relationship between Reynold's Number and Fanning's friction factor.
17	Coefficient of Drag	Understand the variation of the coefficient of Drag with respect to the Reynolds Number of different objects.
18	Finding velocity field using Open CV	Analysis of streakline through hydrogen bubble flow.
19	Determining viscosity of a solution using Ostwald viscometer	To determine the viscosity of a polymer using Ostwald viscometer
20	To study the impact of jet stream	Calculate the reaction force due to change in momentum of the fluid flow when a jet of stream strikes a flat plate or curved surface and compare with the computational result.
21	Comparing heat transfer in turbulent and laminar Flow	Proposing an experiment for comparing heat transfer in Turbulent and Laminar flow
22	Drag reduction in Newtonian Fluid	Verify the drag reduction phenomenon

Table 3: Questions in the reaction survey for DYE

Question Number	Questions	Choice of responses	Score
1	In general, the end semester project enhanced my learning in the lab	1) poor, 2) fair 3) satisfactory, 4) very good, 5) excellent	poor = 1; fair = 2; satisfactory = 3; very good = 4; excellent = 5
2	The project motivated me to go a step beyond the regular lab exercises	1) poor, 2) fair 3) satisfactory, 4) very good, 5) excellent	poor = 1; fair = 2; satisfactory =3; very good = 4; excellent = 5
3	Working on the project fostered collaboration and team spirit	1) strongly disagree 2) disagree 3) neutral 4) agree 5) strongly agree	strongly disagree = 1; disagree = 2; neutral = 3; agree = 4; strongly agree = 5
4	Report writing or presentation helped improve my communication skills and increased my confidence	1) strongly disagree 2) disagree 3) neutral 4) agree 5) strongly agree	strongly disagree = 1; disagree = 2; neutral = 3; agree = 4; strongly agree = 5
5	My favorite part of the project	N/A	N/A

DYE project enhanced learning in the lab

According to the feedback from students, the DYE project helps them brainstorm ideas on the topic they learn during the course and understand the applications in real life. The project serves as a bridge between the concepts learned in the lab and the industrial application. It encourages the student to assimilate knowledge systematically by observation, experimentation and logical reasoning. Over the years, many students find the DYE project to be satisfactory, which adds additional learning and knowledge of the subject. As per Figure 1, more than 50% of the students feel that the DYE project helps them enhance their learning in the lab. The weighted average score as per Table 3 for question 1 is 3.6 ± 0.6.

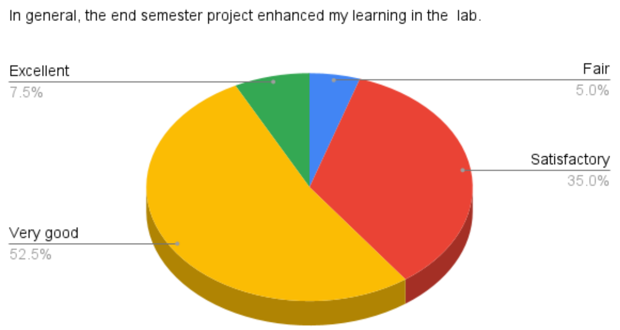


Figure 1. Students' feedback for enhanced learning through DYE project

Motivation to learn beyond the books

41% and 33% of the students rate the DYE project to be very good and satisfactory respectively as indicators of motivation to learn beyond classroom teaching as shown in Figure 2. The project encourages the students to read research papers, articles from journals and read chapters from the relevant books. Reading the scientific paper is the first-time experience for many of the students. The weighted average score as per Table 3 for question 2 is 3.5 ± 0.8.

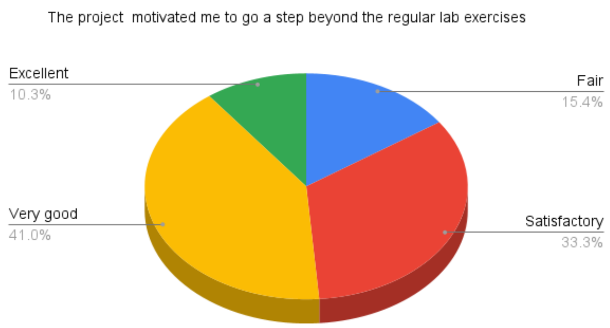


Figure 2. Students' feedback for motivation to learn beyond the regular lab

Collaboration and Team Spirit

Working on the DYE project in collaborative groups develops team spirit and leadership qualities. As per Figure 3, none of the students disagree that the project fosters collaboration and team spirit, indicating a positive impact of the DYE project on developing interpersonal relationships among students in groups. The weighted average score as per Table 3 for question 3 is 4.0 ± 0.6.

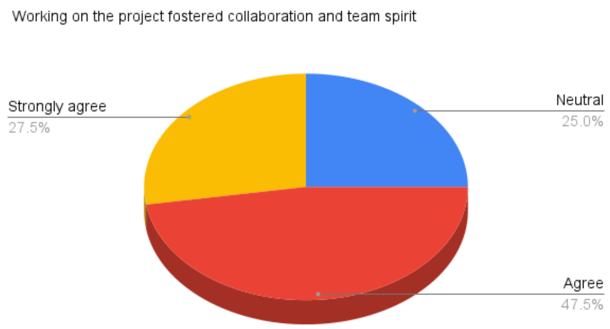


Figure 3. Students' feedback on collaboration and team work

Report writing and Presentation

The teams must submit a final project report, which consists of the aim of the project, a literature review, design and results of the experiment and its application. According to the survey, 32.5% of students strongly agree and 45% agree that the report writing, and presentation improves their communication and increases their confidence. However, 2.5% of students also disagree that report writing and presentation has contributed to their communication skills. The weighted average score as per Table 3 for question 4 is 4.0 ± 0.7.

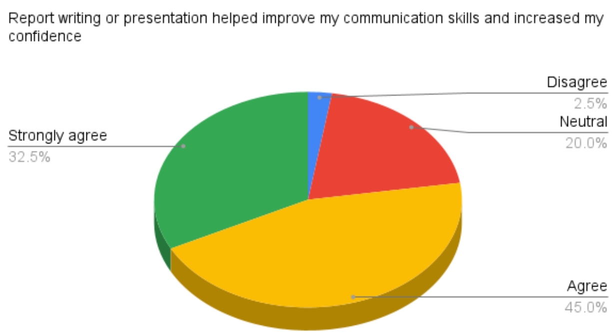


Figure 4. Student feedback for report writing and presentation

My Favourite Part of the Project

Several students listed their favourite part of DYE as tabulated in Table 4.

Table 4: Students favourite part in the project*

Experiment learning
Trying to explore beyond the listed experiments and think of something practical related to the subject
Brainstorming on how to use the experimental set-up to understand the validity of assumptions in the experiment
This project exposed me to research methods and scientific communication.
Presentation part
Designing a new experiment and preparing a report on it
The project helped me to understand the importance of the experiment.
Final presentation
To make the set-up and write the lab report.
Presentation and report
Searching for different parts
Carrying out the experiment and making the video.
To successfully experiment without external help from TA.
Tackle the surprise problems encountered during the experiment.
The presentation
The project required us to make improvisations in case of unplanned circumstances.
Assembling the setup
Making the apparatus work
Working with the team

* Reproduced from the students' reaction survey

The DYE project described here, is similar in outlook to the approaches described by other educators (Hrenya, 2011; Wicker and Quintana, 2000; Kim and Panta, 2012; Wei and Ford, 2015). In general, the DYE project in previous studies is conducted throughout the semester as a stand-alone exercise. In these studies, a particular problem statement or a set of topics to choose is assigned in implementing active learning in the FM courses. However, DYE project discussed in this paper relies on students to find a problem statement and the corresponding experiment which they can work as part of this activity.

The performance of the students in DYE project was independent of their scores in theory FM course. This indicates that DYE project is a beneficial learning tool for students who may not be able to grasp the concepts in the class lecture-style mode of instruction.

Challenges

The integration of DYE project in the laboratory courses can be challenging. According to the reaction survey, some students feel that the time required (~ 6 weeks) to complete the DYE project is not enough along with the regular experiments in the lab course. More manpower in terms of teaching assistants along with multiple instructors may be beneficial to help and guide the students on a weekly basis and to monitor their progress.

Conclusions and Future Directions

DYE is an effective tool which can be incorporated in laboratory courses to engage students and help them get over the monotonous setting of the course. It also helps the students to forge inter-personal relationships, coordination and teamwork.

However, during the hybrid or online offering of the laboratory course, it would be beneficial to include a simulation-based exercise ahead of the DYE project. Another variation of DYE project can be based on experiments in Journal of Visualized Experiments (https://www.jove.com/) and National Committee of Fluid Mechanics Films (http://web.mit.edu/hml/ncfmf.html).

The students may be instructed to expand the knowledge gained from the published experiments; define and perform another experiment.

Acknowledgement

We are grateful to the anonymous reviewers for their insightful comments. We thank the Discipline of Chemical Engineering, IIT Gandhinagar for funding. We also thank the staff and teaching assistants associated with FM laboratory for their assistance. We thank IIT Gandhinagar library for providing many useful research articles on engineering education pedagogy.

Disclosure Statement

The authors declare that they have no conflict of interest.

References

Chua, K. J., W. M. Yang, and H. L. Leo. 2014. "Enhanced and Conventional Project-Based Learning in an Engineering Design Module." International Journal of Technology and Design Education 24 (4): 437–58. https://doi.org/10.1007/S10798-013-9255-7/FIGURES/5.

Feisel, Lyle D., and Albert J. Rosa. 2005. "The Role of the Laboratory in Undergraduate Engineering Education." Journal of Engineering Education 94 (1): 121–30. https://doi.org/10.1002/J.2168-9830.2005.TB00833.X.

Hrenya, Christine M. 2011. "Active Learning in Fluid Mechanics: Youtube Tube Flow and Puzzling Fluids Questions." Chemical Engineering Education 45 (2): 114–19. https://journals.flvc.org/cee/article/view/122162.

Kim, Hyun W., and Yogendra M. Panta. 2012. "Fostering Students' Capability of Designing Experiments through Theme-Specific Laboratory Design Projects." ASEE Annual Conference and Exposition, Conference Proceedings. https://doi.org/10.18260/1-2--21403.

Mandavgane, Sachin. 2020. "Fun with Fluid: An Innovative Assignment in Fluid Mechanics." Education for Chemical Engineers 30 (January): 40–48. https://doi.org/10.1016/J.ECE.2019.11.001.

MILLS, and JE. 2003. "Engineering Education-Is Problem-Based or Project-Based Learning the Answer?" Australas Phys Eng Sci Med 4: 1–16. https://ci.nii.ac.jp/naid/20001056499.

Palmer, Stuart, and Wayne Hall. 2011. "An Evaluation of a Project-Based Learning Initiative in Engineering Education." https://doi.org/10.1080/03043797.2011.593095 36 (4) : 357–65. https://doi.org/10.1080/03043797.2011.593095.

Pérez-Sánchez, Modesto, and P. Amparo López-Jiménez. 2020. "Continuous Project-Based Learning in Fluid Mechanics and Hydraulic Engineering Subjects for Different Degrees." Fluids 2020, Vol. 5, Page 95 5 (2): 95. https://doi.org/10.3390/FLUIDS5020095.

Puleo Jack A. 2020. "A Design-Based Fluid Mechanics Laboratory." Global Journal of Engineering Education 22.

Robert W. Fox, Alan T. McDonald, and John W. Mitchell. 2020. Introduction to Fluid Mechanics . 10th ed.

Wei, Tie, and Julie Ford. 2015. "Enhancing the Connection to Undergraduate Engineering Students: A Hands-on and Team-Based Approach to Fluid Mechanics." Journal of STEM Education: Innovations and Research 16 (2). https://www.jstem.org/jstem/index.php/JSTEM/article/view/1933.

Wicker, Ryan B., and Rolando Quintana. 2000. "An Innovation-Based Fluid Mechanics Design and Fabrication Laboratory." Journal of Engineering Education 89 (3): 361–67. https://doi.org/10.1002/J.2168-9830.2000.TB00537.X.

Seeing With New Eyes: My Professional Development Expedition as an Engineer

Article history
Received
20 November 2021
Received in revised form
27 November 2021
Accepted
27 November 2021
Published online
30 November 2021

Zaki Yamani Zakaria
School of Chemical and Energy Engineering, Faculty of Engineering,
Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor
zakiyamani@utm.my

Abstract
Decision to be an engineer can be affected by hundreds of reasons. After a person successfully becomes an engineer, the next challenge is to pursue with engineering professional development, which is another context in the continuous learning process. This study's research question is "how and what are the trainings and processes for professional development to be a great engineer?" This study was conducted using the narrative inquiry and self-study method under the qualitative research paradigm. I use my blog entries as the primary qualitative data and narrative analysis as the main qualitative data analysis. Looking back more than three decades ago, I discovered the important turning point where I decided to be a chemical engineer. It was from that point of time; I gradually develop my engineering identity which is very crucial to the establishment of an indispensable engineer mind-set and character. Formal and informal education before, during and after university era combined as a meaningful chemical engineering roller coaster expedition. The excitement of learning new knowledge and gaining unique experience everyday resulted to the build-up of a matured chemical engineer. After a while, the process gracefully transformed from personally gaining to the integration of continuous learning and sharing, to benefit likeminded chemical engineering community. By showing this personal journey, I hope to enlighten the progression of professional development of an engineer.

Keywords: Chemical engineering identity, narrative inquiry, self-study, chemical engineer expedition.

Introduction

Being a developed country, Malaysia has tremendous potential to grow and prosper. In order to attain its full potential, the country has to pay a great deal of attention to the quality of engineering education, to ensure qualified engineering graduates, which are instrumental for the nation's growth and sustainable development. As stated by UNESCO, engineering has a significant role in dealing with the global issues from energy, climate change, water, safety and security, poverty, and sustainability problems (UNESCO, 2010). By resolving their own issues, developing countries, such as Malaysia, may play a role in tackling these global issues.

Fundamentally, engineer is an important building block of a nation. The more quality engineer a nation produces, the more developed and prosperous the country is. The profession as an engineer is very imperative to be gazetted to the young generation. In parallel with that, efforts to create interest in STEM among children must be strategically planned and executed by the government. In 2018, the National Council for Scientific and Research Development studied and revealed that Malaysia needs to have 500,000 scientists and engineers by 2020 to deal with the challenges of Industrial Revolution 4.0 (Vijaindren, 2018). Unfortunately, as of 2020, according to Board of Engineers, Malaysia (BEM), Malaysia only has 137,073 registered graduate engineers and professional engineers. For a developed nation, the engineer to population ratio should be 1:100. With a population of 32 million, Malaysia should have 300,000 registered and professional engineers (Fui, 2020). This is indeed a worrying scenario for Malaysia and other developing countries experiencing similar situation. What went wrong? What are the underlying issues brought to this unprecedented scenario? As for the case of young engineers, the realities of engineering practice is dynamic and constantly evolving, often leaving graduates underprepared for the workplace and employers dissatisfied with new engineers.

Every nation desire, plan and do their best to develop the country via a proper education system. The education system is diverse as it covers aspects of science technology and social sciences. Science and technology itself covers broad areas from engineering, technology, medical, architecture and others. After 64 years of independence, Malaysia has produced a lot of engineers. Thanks to the unremitting improvement of education system that among the focus are towards the establishment of engineers.

The next step after graduating is the route to be a professional engineer that is deemed very critical and continuous in the career development of an engineer. Continuous training emerged as a central role in helping engineers and their employers to respond positively to technical and commercial change (Senior, 1995). To encourage engineers to grow, plenty of activities such as workshops, trainings, conferences, lectures, seminars, refresher courses, colloquiums and work based activities were quantified as continuing professional development (CPD) (Schnehage, 2007). Due to numerous unhappy employers, recently Jesiek and his team investigated the early career progression for young engineers to comprehend their evolving job role demands and organizational expectations (Jesiek et al., 2021). He concluded that a synergistic improvement between engineering education and professional development should be performed.

The pertaining issues now are the process and training for young engineers in universities and after they graduate (in their career)? Is the training sufficient to make them a comprehensive and rigorous engineer? Is there a guided process to produce qualified, matured and indispensable engineer? The success of getting an engineering degree is one crucial element, but continuous development of the engineers themselves is another critical aspect. Are the engineers complacent with what they already achieved? Is the engineering degree certificate sufficient to allow them to practice? Did all engineering graduates served as practicing engineer or some of them lost their interest to be an engineer? How about the engineering identity development when they studied engineering? There are plenty of serious worrying questions.

Owing to the above tormenting issue, this study aims to conduct a narrative inquiry and self-study by reflecting on my professional development to be a professional engineer. So far there have not been such studies related to how a person undergoes professional development to be a professional engineer written using narrative inquiry and self-study method. Thus, this paper seeks to fill the existing gaps from the methodological aspects related to this theme. I shared the early stage of how I decided to be an engineer for us to reflect what could be the contributing factor of me choosing this path. After self-determining to be an engineer, I shared the processes I went through all the way until I became a professional engineer

Methods

The paper focuses on answering the research question "how and what are the trainings and processes for professional development to be a great engineer?" This paper was piloted using the narrative inquiry method under the qualitative research paradigm. This qualitative research method is based on the one introduced by (Connelly and Clandinin, 1990), which was then improvised further by (Clandinin and Caine, 2013). The narrative research design centralizes on the narrative of the life of an individual.

The fundamental principle of narrative inquiry is that humans are storytelling creatures who are individually or socially dwelling inside their own stories. Consecutively, the study of narrative, conferring to Connelly & Clandinin (1990) is a research on how humans drive their lives in the world. In the context of educational research, this concept is developed into the perspective that education and educational researches are the construction and reconstruction of stories from one individual and a group of people socially. Learners, teachers, and researchers are storytellers and characters in their own stories or tell other people's stories.

In order to answer the research question, I have analysed my own professional development journey from being a high school student, then to an engineering student to becoming a practicing engineer and finally a professional engineer. I look through the lens of narrative inquiry and self-study to revisit my experiences in various selected professional developments as an engineer. Personal blog entries (Chemical Engineering World Blog) were employed as the primary qualitative data (Zakaria, 2007), and narrative analysis as the main qualitative data analysis. Personal blog entries were chosen because it is one method within a set of data collection methods and primarily for gathering information about experiences, perceptions, and feelings. Blogs have potential as a research tool for a range of purposes, including data collection (Wilson et al., 2015). Blog entries are also an intriguing form of communication and personal expression that resulted to the realization among researchers on the value that these media present as sources of data for research (Jones and Alony, 2007).

Narrative inquiry and self-study were chosen as the main qualitative data analysis because researchers commonly employ them to understand how research participants construct story and narrative from their own personal experience. Possible multiple theories and concepts that support the professional development in a person/career were identified for every episodes. These theories include Social Cognitive Career Theory, Self-Determination Theory, Transformative Learning Theory, Adult Learning Theory - Kolb's Learning Cycle, Circumscription and Compromise Theory, Community of Practice as a Social Theory of Learning. Simultaneously, concepts such as self-efficacy, transformative learning, and independent learning method were also considered in this study.

Findings and Discussion

The beginning of the adventure

Everything started when I was a venturesome adolescent and being in a background where my father was an organic chemistry professor. Being at that age, I was eager to learn and explore many things in a different way compared to when I was a child. I started to seek for my personal identity, interest and goal. I was fascinated when I first saw the chemical structures and formulas from my father's chemistry book. The chemical structures in the shape of pentagon, hexagon, heptagon and others look intriguing and fascinating to me. At that age, I felt that it could be a cool stuff to master and able to explain about the polygons.

Since my father teaches organic chemistry in a local public university, he has dozens of related text books neatly arranged in our house and his office. In fact, he also co-authored an organic chemistry text book in our mother tongue language. When I was 14, I read one of his organic chemistry books and willingly motivated to learn chemistry by myself. When I was 17, I wanted to have a career associated with chemistry. I sturdily believe that this resemble a classic example of background contextual affordances such as families, particularly parents, whom have strong influences on the child's career choices (Ing, 2013). Even though my father did not persuade me into any career direction, his chemistry indulgent affected my interest and my future direction that is inclined to chemistry. Reflecting back in a deeper thought, I realized that my experience could be explained by the Social Cognitive Career Theory (SCCT)(Lent, 2004). According to SCCT, the choices people make and the actions of putting their choices into practice are related to their interests (Maiorca et al., 2021). The only thing to note, instead of majoring in chemistry, I decided chemical engineering pathway, mainly because I felt that it is more glamorous and prestige, based on what I knew at that time.

I recalled my uncle suggesting me petroleum engineering; however, I politely responded that I prefer chemical engineering. Although information on chemical engineering was scarcely available, I have the idea that this career is quite diverse and at the same time has specific crucial demand. Chemical engineers can fit and be in various industrial sectors and it is also regarded as a universal engineering discipline.

Back then at the end of my secondary school, my first choice was chemical engineering and my second choice was biochemistry. I was not really sure why I wanted to be a chemical engineer. But I know for sure it is not an influence of my parents such as majority of Saudi Arabian engineering students (Labib et al., 2021). I was also not pursuing chemical engineering because of it is a well-respected and well paid job as believed by most American chemical engineering students (Shallcross, 2002). The only thing I know is that I just love chemistry.

I did not know about the terminology of STEM (science, technology, engineering and mathematics) back then. But thinking about it, I realized that my interest in STEM could also be a motivating factor in me pursuing to be a chemical engineer. If I were to give straight direct answer of the reason, it would be due to my interest in chemistry. Even though I liked chemistry, I have no interest to be a chemist. The idea of becoming an engineer sounded better and by associating it with chemistry, I decided chemical engineer is a profession I would become. Many years after that, I realized that I was not the only one who picked chemical engineering due to my fond of chemistry. I can say majority of chemical engineers I met and chemical engineering students I teach (after I become a lecturer), chose chemical engineering because of their affection towards chemistry. In my opinion, this perception should be corrected. Chemical engineering is not solely about chemistry. It is more on mathematics and physics with certain extend of chemistry twist in between.

The journey during my tenure as a chemical engineering student was very challenging. There were several moments where I felt that it may not be possible for me to continue this course because of the difficulties in several subjects such as engineering mathematics, thermodynamics and reaction engineering. However, my engineering self-efficacy has driven me to the end, and I eventually graduated as a chemical engineer. Self-efficacy leads to an enduring interest in an activity. Self-efficacy is the self-perceived competence of an individual as stated by Bandura (Bandura, 1978). Every engineering student and young engineer should have strong self-efficacy to drive them to the end and also to keep them moving to get better and better.

To be honest, I was unaware of what chemical engineers do and what the industry is like. I could not imagine it due to lack of exposure and information. At that time, there was not internet to speed up information seeking. We relied on magazines or books that we can borrow from the library. We also count on information shared by those older and of more experience than us, but only God know the reliability and the accuracy of the information. I just knew that I want to be a chemical engineer and that my motivation is constructed around that idea. The motivation within me was very obvious and I started to develop my mind-set and thinking as a person who will be a chemical engineer. This motivation is critical driving force as it helps to make me move and focus to one prime direction as stated by (Haque et al., 2014):

> *...Motivation is a way of creating high level of enthusiasm to reach organizational goals, and this situation is accommodated by satisfying some individual need. Basically, motivation refers to achieving organizational main goals by satisfying individual employee's needs or demands (p.2)*

After completing my high school education, I pursued my A-Levels and took three core subjects which are essential for engineering: Physics, Chemistry and Mathematics. Then I continued my bachelor degree in chemical engineering. I managed to get a place in Bradford University, United Kingdom. I was unlucky because in our contract, practical training or sandwich course is not included by our sponsors. Therefore, we didn't have any valuable practical and industry exposures. That didn't matter and I kept on studying until I graduated in 1999. Reflecting on this particular episode, I can now reflect to the concept of Self-Determination Theory as introduced by (Ryan and Deci, 2020). No matter what the challenges were, I kept myself going and eventually graduated.

Post graduate - Research and Development (1999-2002)

After completing my degree, I returned to Malaysia, immediately seek for an opportunity to work and was appointed as a research assistant for 5 months in UTM. I joined "Chemical Reaction Engineering Group" (CREG), where its main research at that time was developing a single step conversion of natural gas to gasoline using zeolite catalyst (Saidina Amin et al., 2001). It was a very interesting topic and that encouraged me to further my chemical engineering master's degree in it. Hence, I then became a full time research student and my research title was *"Optimization of Oxidative Coupling of Methane (OCM) Using Experimental Design"*, which is part of the natural gas to gasoline research project (Saidina Amin and Zakaria, 2012).

I observed myself shifted from undergraduate learning style that focused on the conventional teacher-centred learning approach to a more matured and independent learning method (Jarvis, 2018). The process of learning was different but I am glad that I am comfortable with it. The learning initiative originated from me, my intrinsic motivation to learn and understand new knowledge. I began appreciating every moment at work and cherished the fact that I am learning from other more experienced and knowledgeable people within my circle. For example, I informally learned from my seniors, technicians, lecturers, supervisor, technicians, suppliers and others. This was a transition period which I can say related to an experience in new learning domain as depicted by Mezirow in his Transformative Learning Theory (Kitchenham, 2008). I enhanced my technical writing skills, communication and presentation skills and others while doing masters. In brief, a huge chunk of the learning and professional development was instigated by my own, which I utterly enjoyed very much.

Oil & Gas Exposure – Servicing Company (2003-2005)

After completing my master, I was offered a job as chemical technologist for a local oil and gas servicing company. In a year, I became a project/chemical engineer in the same company. My main task was to lead the "internal pipeline chemical cleaning" (IPCC) project for a local oil company. We basically have to assist the oil company to reduce corrosion activities inside the downstream pipeline and prolong the life span of it. To efficiently and effectively monitor corrosion activities in the pipelines, we utilized latest corrosion monitoring techniques such as electronic resistant probe (ER) and field signature method (FSM).

I was also in charge of the oil and gas specialty chemicals. I travelled to a number of offshore platforms in East Malaysia to conduct deoiler and descaler tests (Figure 2 (a) and (b)) for their oil reservoir at PM9 Zone, South China Sea. It was very challenging and fun performing those tasks. I love going offshore because the working hours are less compared to the amount of time we spent on the offshore platform. The foods were marvellous and comparable to 5 star hotels. Entertainment and other activities such as television, movies, snooker, Ping-Pong, gymnasium and reflexology chair were made available for the platform dwellers. To be able to go offshore, I have to undergo Helicopter under Water Escape (HUET) training and get myself an offshore passport. With this job, I travelled extensively and visited neighbouring countries, Singapore and Indonesia, for work purpose. In Kalimantan, Indonesia, I joined our company principal to conduct bottle test field trial for local oil company on their onshore oil rig. It was a very interesting and exciting assignment because I got to see how simple the setting of an onshore oil rig because in Malaysia we only have expensive and complicated offshore oil rigs/platforms.

The whole practical exercise that I went through can be related to the Adult Learning Theory (Merriam, 2008), particularly Kolb's Learning Cycle (Figure 1), which I found to perfectly fit what I experienced. Kolb's Learning Cycle is based on the Jean Piaget's focus on the fact that learners create knowledge through interactions with the environment and his work (Kolb, 2015).

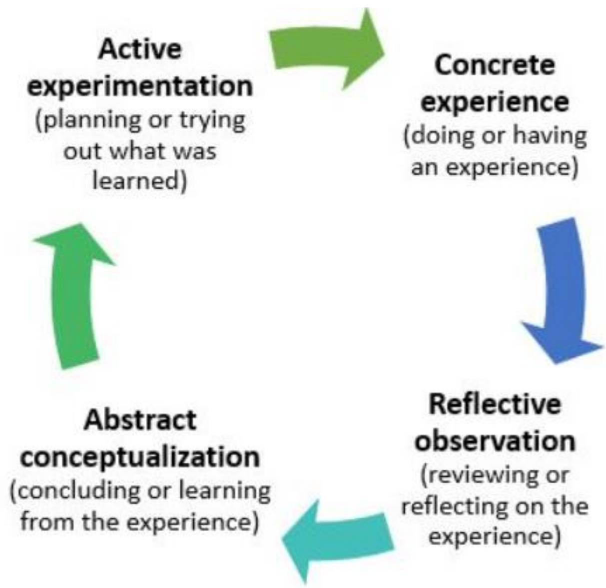


Figure 1: Kolb's learning cycle

Kolb's learning cycle concept is enhanced by Kolb's Four Stages of Learning that are (i) Concrete Experience, (ii) Reflective Observation, (iii) Abstract Conceptualization; and (iv) Active Experimentation.

To better illustrate the relationship, I selected a specific practical process during my work in the oil and gas industry. The first stage stated that the learning process begin with "Concrete Experience". In 2003, I started my first endeavour working in a site of a petroleum processing company. Our task was to protect the pipeline by internal pipeline chemical cleaning. I never imagine or expected to do such work. Honestly, I did not know or have ever imagined that there is a job like that. The trip to a gas processing facility located at the east cost of Peninsular Malaysia in early January 2003 was my first time and it was a very enriching one that I learned a lot in terms of the technicality, management and operation. Not only that, I immediately found myself to lead a group of contract workers, whom are all older and more experienced than me. I have to properly communicate and lead them to accomplish my task. Kolb stated that the first stage can either be a completely new experience or a reimagined experience of what had happened. In this stage, I was highly engage in the 5 days project and the key to learning at this point is by being involved. It is not sufficient if I only learn about it by listening to my superior or manager's briefing. Bottom line is to be actively engaged in the task.

The second part of Kolb's Four Stages is Reflecting Observation and into certain extend, even not thorough, I did glanced to reflect on the overall experience during the IPCC project. Every day after the sub-task was completed; I recalled the experiences and often ask questions and discussed it with my colleagues and superiors on the task, how it went, what should be done better and how to improve it. This occasionally occurred at our hotel and over dinner. From this exercise, I managed to identify any discrepancies between their understanding and the experience itself. The reflection observation learning process is optimum within the 12 hours period after the daily sub-project ended as I can still clearly recall on the detailed performed tasks. For example, I did asked about the methods of how to launch a pig in the 10" and 48" (Figure 2(c)) pipeline that requires strategic coordination of valves operation between our team and the client's team to create safe pressure difference to enable the pig to initialize travelling (Figure 2(d)). Pig in this context (pigging activity) is an equipment that is inserted in pipeline for various purposes such as for cleaning or for carefully spreading chemical film in the internal side of the pipeline or others.

Next will be the Abstract Conceptualization where I make sense of the events. I attempted to draw conclusion of my experience by reflecting on my prior knowledge, using ideas which I am familiar or discussing possible theories/ concepts/ hypothesis/ methods with my colleagues. I began to move from reflective observation to abstract conceptualization when I began to classify concepts and form conclusions on the events that occurred. This involves interpreting my experience and making comparisons to my current understanding on the concept. The tasks/ activities became clearer as I assisted to document them into various reports such as Method of Statement (MOS), Emergency Response Procedure (ERP), Job Completion Report (JCR) and Quarterly Progress Report and others. The reports require observation/ findings, data capturing/ analysis, suggestions/ recommendations and others. At first, I am not familiar with the reporting and documentation exercise, but with time I get better and was able to handle it myself. From this exercise, the overall tasks or bird eye view of the entire project makes sense.

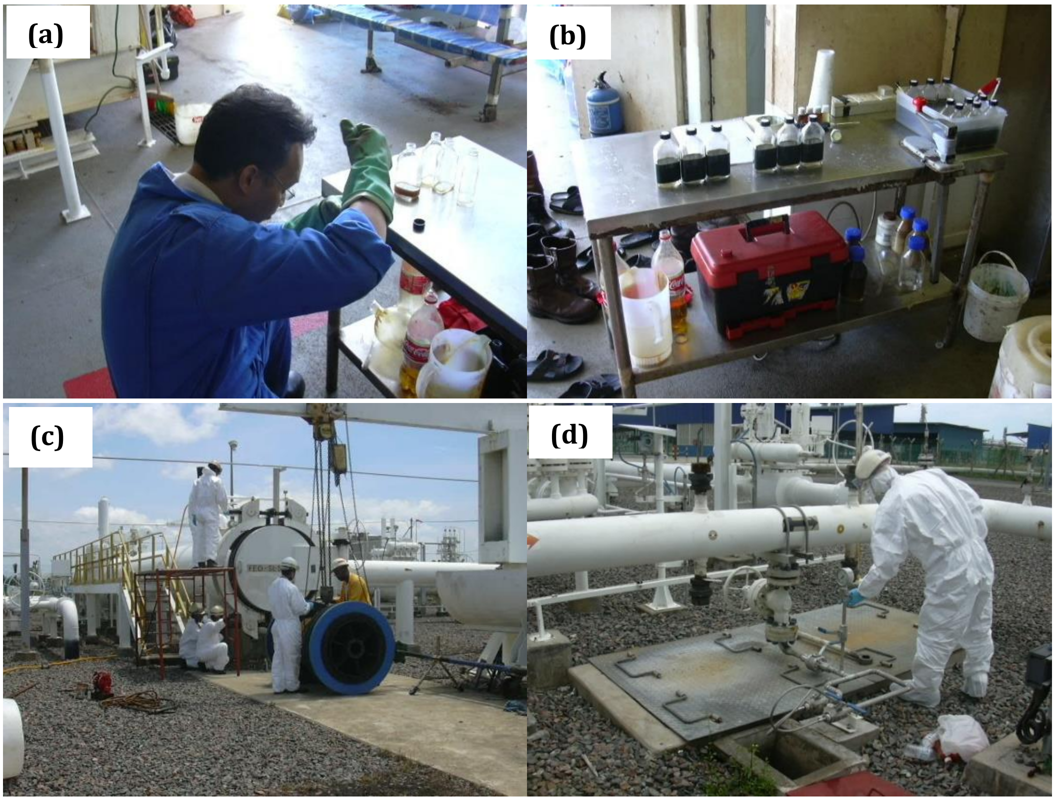


Figure 2: (a) Performing bottle test at one of the offshore platforms I was assigned to (b) My work kit to perform the bottle test (c) A 48" pig was about to be set up in a 48" gas condensate pipe launcher (d) Checking pressure reading on the gas pressure regulator at the receiver side of a 10" pipeline

The final stage is the Active Experimentation where it is also referred to as testing stage. In this context, I return to participate in the same project after three months, this time with the goal of applying my previous conclusions to new experiences. Thereafter, every quarterly I managed to improve and get sharper. I am able to make predictions, analyse tasks, and make plans for the acquired knowledge in future activities. I allow myself to put my knowledge into practice and showed how it is relevant to me, and how I can ensure that the information is retained in the future. This can be seen when I managed to take part in the planning, mobilization-demobilization, project execution, management and reporting of the project. I also managed to develop good relationship with the client and at the same time maintain my professionalism as an engineer and also the representative of the company I worked with.

As Kolb's learning theory is cyclical, one can enter the process at any stage in the cycle. Even though I never formally knew about the theory, as I associate my past working experience with the Kolb's learning theory, I realized that I am actually learning as per say in the context of On-Job-Training. The cycle should be completed in entirety to ensure that effective learning has taken place. Each stage is dependent on the others and all must be completed to develop new knowledge.

Oil & Fats Industry – Refinery (2005-2008)

I love my oil and gas career but I was unfortunate because I could not continue being in that industry. The company management has bigger plans and they moved to Kuala Lumpur, the capital of Malaysia, in quest to seek for more business opportunities. I was instructed to transfer which I could not do because I don't want to hinder my wife's career establishment as a lecturer/researcher/consultant in UTM and we also have just purchased a house in Johor Bahru, the same year. That was the situation at that time. Personally, I learned to compromise and negotiate with the situation. Everything will not go our way or how we plan and wanted it to be. Hence, we need to have acceptance, adapt and move forward. I swiftly seek for a new engineering job that can allow me to keep on contributing my expertise and at the same time for my family's survival.

My state of mine at this time can be associated with the Circumscription and Compromise Theory. This theory, developed by Linda Gottfredson in 1981, attempts to describe how career choice develops in young people. Many developmental theories focus on how an individual's self-concept develops with age. Circumscription and compromise also focuses on the development of an individual's view of the occupational choices available. The theory assumes that we build a cognitive map of occupations by picking up occupational stereotypes from those around us. Occupations are placed on this map using only a small number of dimensions: sex-type, prestige level and field of work. As young people build this map, they begin to decide which occupations are acceptable and which are unacceptable — those which fit with their own developing self-concept and those which do not.

I seek for other jobs and managed to get one in a physical refining plant in the oil and fats industry located in Johor Bahru, but 50 km away from my house. This is a whole new chapter and totally different from my previous job. I was required to punch in and out every time we enter or exit the refinery/factory. Life is no longer as flexible as before. I don't have ample time to do my work and that made me work longer hours and I always reach home when it's already dark. I don't really mind because it's a new working environment and I know I have to learn as fast as possible, just the same principle as the Kolb's Learning Cycle. I set my target to know everybody around my circle of work as soon as possible. Reflecting this intention, I can relate it to the Community of Practice as a Social Theory of Learning (Farnsworth et al., 2016).

The workplace community I was in consisted of plant supervisor, plant operators, maintenance supervisors, colleagues such as process engineers and production executives from other departments. All of them have great experiences and certain specific technical knowledge and the whereabouts of the workplace. It turns out that by casually socializing with them, I can swiftly and effectively learn. I can discuss and consult with them as well. However, I was reminded by manager not to be too close or too intimate with my down-line staffs. At first I was confused with this advice and felt that it does not make sense. This is because, my reasoning back then was, and it is good to be close to our staffs so we can work productively and comfortably. It took me 6 months after that to realize the logic behind the advice where I need to evaluate the performance of all my staffs. The evaluation will affect the annual salary increment and yearly bonus. At that time, I was already quite close with some of my staff and I felt that it is difficult to evaluate them fairly and professionally if we are emotionally and socially attached to them. I may tend to grade those close to me with slightly higher marks, only for me to be reminded by my manager that I was biased when I submitted my evaluation.

Here I realized that I have indulged in a conflict of interest issue and I was not professional and ethical in giving my marks. I then recalled the advice given to me by my manager earlier to draw a thin line border to control my relationship with my staffs. As a person who has not formally be educated in ethics or ethics case studies/examples during the undergraduate years, I learned the hard way. I learned this through the context of Adult Learning Theory. I also realized that, there are more than just being qualified and getting certificate as an engineer. In university, me and my friends have not been taught or properly trained to be a good leader, team player, possess immaculate soft skills such as communication, presentation, writing skills. We have not been taught on emotional intelligence and empathy. I have to learn all of the above mentioned soft skills by myself. I learned through my own experience and luckily I really wanted to improve, and could relate this to the Self Determination Theory (Deci and Ryan, 2012). I was determine to improve myself to be good and an indispensable engineer. This is when I see that I improved cognitively and technically with time.

On the first week of my tenure as a process engineer, my first task given by my Manager was to identify and list down all the valves in the plant I was in charge of. It was an interesting and good assignment. It made me traced the entire pipeline from the feed tank to the plant and to the product tank. I learned a lot of technical knowledge regarding valves. I know and understand various types of valves, brands, origin, sizes, spare parts, principles, operations, tag numbers etc. In addition to that, indirectly, I learned about the plant process and operation. That was just the beginning. Being in a process plant is a perfect place to learn and put in practice my unit operation knowledge. It also gave me a better comprehension on what process control is all about. I learned about other supporting units like heat exchangers, cooling towers, high pressure boilers, utility boilers and much more. During plant shut down, I learned a lot. Techniques on ensuring the fastest and effective way to cool down the plant, managing and coordinating a team of people to service the plant, conducting air test, steam test and driving the plant start-up are among some knowledge I acquired.

The learning curve continued every day and never stopped. Not only that I learn about all the technical aspects, handling manpower and managing conflict is another challenging area that I made myself good at. Manpower is not an easy matter to deal with. Some of my down line manpower never experienced any disciplinary action taken when they violated certain laws such as coming in late and simply not coming to work. Despite a series of reminder and warning, the bad attitude still continues. I could not stand it. Together with my senior colleague, we enforced the discipline and forced them to obey. We gave the problematic staffs some disciplinary action. We wanted them to learn a lesson and be more serious towards their responsibility and work. They got the message and swiftly improved positively at work.

The Turning Point to be Professional Engineer (2007)

I have to say that even though I am a practicing chemical engineer, I also have the desire to be an academician. For the past five years after I became an engineer, I have attempted five times to get to an interview to be an academician. I almost gave up, thinking that I will end up becoming an engineer for the rest of my life. Deep inside, I know that I can contribute far more as an academician compared to as a practicing engineer. Even as an academician, I still regard myself as a chemical engineer but then in the educational sector. My self-determination and motivation was still high. Reflecting back the past five years, I knew I must improve myself and introduce a WOW factor so that I can be accepted as an academician. Besides depending on my engineering practice experiences, I decided that I must start leading my way to be a professional engineer.

I was still a practicing engineer when I consulted few friends that I know who are a professional engineer and also the Board of Engineers, Malaysia (BEM) and Institution of Engineers, Malaysia (IEM). I managed to get in touched with a very experienced Professional Engineer who became my mentor. Although he is 350 km apart from me, I regularly communicated with him and also visited him every quarter of the year to report on my progress.

My mentor was a very strict and wise person. He advised and guided me brilliantly. At one point, I was reminded by him that I could not have repeated engineering activities month after month. I must diversify and show more engineering activities. To achieve that, I need to request for other engineering tasks and projects to enable me to have a more colourful activities reported in my Logbook, Final Project Report and Training & Experience Report. In 2008, I was successfully accepted as an academician in a local university, the same university I have attempted to apply for five straight years. My mentor said that my move to be an academician was a perfect one as I can decorate more variety of engineering activities in my Logbook. Finally in October 2010, I passed my Professional Interview as a professional engineer and began a new chapter. The process was definitely not easy, but again my intrinsic determination, as depicted by the Self Determination Theory once again facilitated me to emerge victorious.

Serving as a Professional Engineer (2010 onwards)

The year 2010 was an amazing year for me. I was working on my PhD and I earned my Professional Engineer status, granted by BEM. Three months after that I sat for an interview to be a Chartered Engineer under the Institution of Chemical Engineer (IChemE), UK. Two months after that, my application to me a Chartered Engineer was successful. Ever since that, I do my part to create awareness, wrote a blog post to share information on how to be a Professional engineer (Zakaria, 2014). I also help graduates who wanted to apply by signing, stamping and endorsing their application besides also providing advice or consultation to young engineers and engineering students. I ensured that I will support or attend any activities conducted by our IEM or IChemE student chapters in the university.

On top of that I keep on developing myself by participating in various technical visits arranged by IEM Southern Branch. Among the technical visits was the Legoland construction project at Nusajaya, Johor; NEWater Facility Plant in Singapore (Figure 3(a)); MRT Construction project in Singapore; Claytan Group at Air Hitam (Figure 3(b)), Mechmar Boiler at Pasir Gudang, Johor (Figure 3(c)); Malakof Power Plant at Tanjung Bin, Johor; and INSTEP Virtual Technical visit (Figure

3(d)), to name a few. All of the technical visit were unique and provided me numerous experiences that I can relate to the Kolb's experiential learning theory (Healey and Jenkins, 2000). Although all of the technical visits are unique and a one-off type of experience, it is still worthy and precious as I learned to relate, understand and appreciate other engineering discipline domains. The technical visit rejuvenates me as it breaks my ordinary life-job routine. The technical visits also allow me to socialize with other practicing professional engineers, thus widening my networking horizon. This learning and professional development differs a bit from the Kolb Learning cycle previously discussed during my oil and gas endeavour tenure (because this was my job scope that I repeatedly performed and improved along the way).

In mid-2021, I decided to be active in IEM and found myself dynamically involved in the Safety Engineering Special Interest Group (SESIG), under IEM. I was elected as SESIG committee member and I am presently doing my best to contribute to the nation through IEM. Simultaneously, I am also leading a team under a project called Safety Champions in Engineering Education, a fellowship program organized by the Royal Academy of Engineering (RAE), United Kingdom that commenced in the third quarter of 2021. Having experienced as a practicing engineer and now actively involved in teaching as well as venturing into engineering education, I am doing my best, my part, to contribute the best to the country, region and world. I sincerely hope and pray that our next generation of engineers will be of high quality and resilient. I wish that my professional development expedition as an engineer will provide insightful ideas, new dimensions and context for young engineers to mature as an indispensable engineer.

Conclusion

Reflecting on my professional development expedition to be a professional engineer, it can be concluded that there are plenty occasions and factors that serves as a training process in developing and shaping me to the state I am now. Upon seeing the past experiences with new eyes, I realized that multiple theories can be deeply associated with specific scenario. The integration of the contributing theories will be my focus on future narrative analysis and self-study. The narrative of my journey above also teaches us that the journey of a person's professional development is unique and personal.

Figure 3: (a) Technical visit to Newater Facility, Singapore in 2008; (b) Clay pipes products from the technical visit to Claytan Group in Air Hitam, Johor in 2008 (c) Technical visit to Mechmar Boiler company in Pasir Gudang, Johor in 2012 (d) INSTEP Virtual visit, Terengganu in 2021.

The findings of this study have convey that an engineer's professional development involved various reasons, factors, motivation and could be connected to relevant social theories. Most importantly, a synergistic exertion between engineering education (before, during and after higher education) and professional development (before and during engineering employment) should be performed. This process could motivate and aid engineers to be more resilient and indispensible, making them useful for their employer, community and nation. I sincerely hope that my professional development as an engineer narratives can provide at least some useful information for fellow young engineers. I also believe it is good if other professional and practicing engineers out there can do the same for others to benefit. It will be a great contribution.

Acknowledgement

I would like to express my gratitude to Universiti Teknologi Malaysia (UTM) (http://www.utm.my) and the Ministry of Higher Education Malaysia (MOHE) for supporting this project under the UTM Matching Grant (Ref. No: PY/2016/06327; Cost Center No. Q.J130000.3023.00M94).

References

Bandura, A. 1978. Self-efficacy: Toward a unifying theory of behavioral change. Advances in Behaviour Research and Therapy, 1, 139-161.

Clandinin, D. J. & Caine, V. 2013. Narrative inquiry. Reviewing qualitative research in the social sciences. Routledge.

Connelly, F. M. & Clandinin, D. J. 1990. Stories of Experience and Narrative Inquiry. Educational Researcher, 19, 2-14.

Deci, E. L. & Ryan, R. M. 2012. Self-determination theory. Handbook of theories of social psychology, Vol. 1. Thousand Oaks, CA: Sage Publications Ltd.

Farnsworth, V., Kleanthous, I. & Wenger-Trayner, E. 2016. Communities of Practice as a Social Theory of Learning: a Conversation with Etienne Wenger. British Journal of Educational Studies, 64, 139-160.

Fui, W. C. 2020. Time we recognise and retain our engineers. New Straight Times, February 19, 2020

Haque, M., Haque, M. & Islam, M. S. 2014. Motivational Theories – A Critical Analysis. 8.

Healey, M. & Jenkins, A. 2000. Kolb's Experiential Learning Theory and Its Application in Geography in Higher Education. Journal of Geography, 99, 185-195.

Ing, M. 2013. Can Parents Influence Children's Mathematics Achievement and Persistence in STEM Careers? Journal of Career Development, 41, 87-103.

Jarvis, P. 2018. Learning to be a person in society. In: ILLERIS, K. (ed.) Contemporary Theories of Learning. 2nd Edition ed. London: Taylor & Francis.

Jesiek, B., Buswell, N. & Nittala, S. 2021. Performing at the Boundaries: Narratives of Early Career Engineering Practice. Engineering Studies, 13, 1-25.

Jones, M. & Alony, I. 2007. Blogs – The New Source of Data Analysis. Faculty of Commerce - Papers, 5.

Kitchenham, A. 2008. The Evolution of John Mezirow's Transformative Learning Theory. Journal of Transformative Education, 6, 104-123.

Kolb, D. A. 2015. Experiential Learning: Experience as the Source of Learning and Development, New Jersey, Pretince Hall.

Labib, W., Abdelsattar, A., Ibrahim, Y. & Abdelhadi, A. 2021. What Motivates Students to Study Engineering? A Comparative Study between Males and Females in Saudi Arabia. Education Sciences, 11.

Lent, R. 2004. Toward a Unifying Theoretical and Practical Perspective on Well-Being and Psychosocial Adjustment. Journal of Counseling Psychology, 51, 482-509.

Maiorca, C., Roberts, T., Jackson, C., Bush, S., Delaney, A., Mohr-Schroeder, M. J. & Soledad, S. Y. 2021. Informal Learning Environments and Impact on Interest in STEM Careers. International Journal of Science and Mathematics Education, 19, 45-64.

Merriam, S. B. 2008. Adult learning theory for the twenty-first century. New Directions for Adult and Continuing Education, 2008, 93-98.

Ryan, R. M. & Deci, E. L. 2020. Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. Contemporary Educational Psychology, 61, 101860.

Saidina Amin, N. A., Anggoro, D., Zakaria, Z. Y., Prasetyoko, D., Tan, E. F., Law, K. M. & Esam, A. 2001. Catalytic activity of Cu-ZSM-5 and HZSM-5 zeolite for single step conversion of methane to liquid hydrocarbon.

Saidina Amin, N. A. & Zakaria, Z. Y. 2012. Optimization of Oxidative Coupling of Methane Using Response Surface Methodology. Jurnal Teknologi, 39, 35â€“52.

Schnehage, C. 2007. Continuing Professional Development (CPD) and the engineer. 10-11.

Senior, C. 1995. Strategies for Professional Development in Engineering. Industry and Higher Education, 9, 236-240.

ShallcrosS, D. 2002. Perceptions Of The Chemical Engineering Profession - Results Of An International Survey.

Unesco 2010. Engineering: Issues, Challenges and Opportunities for Development. Paris, France.

Vijaindren, A. 2018. Malaysia needs 500,000 scientists and engineers by 2020. New Straight Times, August 13, 2018

Wilson, E., Kenny, A. & Dickson-Swift, V. 2015. Using Blogs as a Qualitative Health Research Tool: A Scoping Review. International Journal of Qualitative Methods, 14, 1609406915618049.

Zakaria, Z. Y. 2007. Chemical Engineering World Blog. Chemical Engineering World Blog [Online]. Available from: http://chem-eng.blogspot.com 2021].

Zakaria, Z. Y. 2014. How to be a Professional Engineer (PE) with IR Status? Chemical Engineering World [Online]. Available from: http://chem-eng.blogspot.com/2014/07/how-to-be-professional-engineer-pe-with.html [Accessed July 8, 2014 2014].