ACHIEVEMENT OF PROGRAMME OUTCOMES THROUGH INTEGRATED PROJECT AS AN INNOVATIVE APPROACH FROM A TEACHING AND LEARNING PERSPECTIVE

NURTANTIYANI ALI OTHMAN1,2*, SITI ROZAIMAH SHEIKH ABDULLAH2, MOHD SOBRI TAKRIFF2, NORLIZA ABD RAHMAN2, NOORHISHAM TAN KOFIL1, MANAL ISMALI2, SITI ZULAIKHA HASSAN2

1Centre for Engineering Education Research, 2Department of Chemical and Process Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor DE, Malaysia
*Corresponding Author: tantiyani@ukm.edu.my

Abstract

An introduction of integrated project (IP) where the elements of several subjects studied were put together is an innovative way of enhancing students’ understanding of how the topics related to each other. This paper discusses outcome-based engineering education (OBE), the lessons learned, determined by the Board of Engineers Malaysia (BEM), the challenges of teaching and learning in engineering, and the learning outcomes and components of IP. Based on inputs where the existing feedback mechanism in the quality management system include an online course assessment system, student dialogue sessions and exit surveys, the improvements are made to teaching and learning activities such as the introduction of IP from the first year of study, open-ended laboratory assignments, formalisation of industrial visits and lectures as part of the learning activities. The effectiveness of the mechanisms for gathering students’ feedback was assessed and reported on in this paper that help to promote future improvement to enhance their effectiveness.

Keywords: Outcome-based Engineering Education, Integrated Project, Continual Quality Improvement, Stakeholders, Student.

1. Introduction

In mid-2000 the engineering education system in Malaysia started implementing the learning approaches of outcome-based education (OBE) and its accreditation requirements for engineering programme studies set by the Board of Engineers Malaysia (BEM). The introduction of the integrated project (IP) where the
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elements of several subjects studied were put together is an innovative way of enhancing students' understanding of how topics relate to each other [1]. The OBE focuses on technical knowledge as well as the fundamentals of the engineering field such as generic skills, effective communication, teamwork and professionalism. Thus, the conventional methods of teaching and learning in the form of lectures, assignments, quizzes and examinations alone are unable to achieve the learning outcomes. To achieve the targeted learning outcomes is a significant challenge for educators in the engineering field. To deal with the challenges, engineering educators need to approach the teaching concept creatively and build on the innovative learning process to facilitate the course and programme outcomes of study to be successfully achieved.

The Department of Chemical and Process Engineering (JKKP), Universiti Kebangsaan Malaysia, has introduced and implemented IP as one of the delivery methods in the chemical and biochemical engineering programme to achieve its targeted learning outcomes which were started in early 2006. The delivery method through IP was developed and implemented based on student and industry feedback. Although the methods of teaching and learning through IP discussed in this paper only focus on the chemical and biochemical engineering field, it would be very easy to adopt them to the others engineering disciplines. Learning outcomes are statements about what a student should know and be able to do towards the end of the study period [2]. It deals with the knowledge, skills and attitudes acquired during study in higher education institutions. Therefore, BEM [3] established twelve learning outcomes in 2012 as minimum requirements to be achieved by each graduate programme to qualify for engineering education accreditation.

The learning outcomes that must be fulfilled include engineering knowledge, problem analysis, design/build solutions, engineers and society, research, current issues, communication, lifelong learning, environment and sustainability, ethics, working as an individual and teamwork, project and finance management [3]. Each engineering programme is required to develop the learning outcomes by considering all these elements that have been set by the BEM and getting feedback from various engineering programme stakeholders including students, alumni, and members of the industry, professional bodies and government agencies. The learning outcomes of the course and programme need to go through a cycle of continuous improvement covering the curriculum, delivery methods, programme assessment and measurement methods.

The development of the engineering curriculum based on the constructive alignment approach was different before OBE implementation. Figure 1 shows the difference between the traditional curriculum and the OBE approach. The development of the engineering curriculum by the OBE approach begins by identifying the attributes to be achieved by the students. Having determined the desired learning outcomes, an appropriate measurement method for each learning outcome must be identified. The correct method and measurements are needed to ensure the student’s learning process can be measured and evaluated. In addition, the engineering curriculum should also be improved periodically. Therefore, the objective of this study is to improve the curriculum in the department where the student feedback from the achievement of student learning outcomes is measured and evaluated. Furthermore, the response of the stakeholders should be referred to
occasionally to ensure the curriculum and learning outcomes remain relevant to industry needs.

Figure 2 summarises the construction and improvement cycle in the engineering curriculum. Compared with the elements of the learning outcomes set by the BEM, the traditional methods of teaching and learning in the form of lectures, assignments, quizzes and exams are unable to achieve the targeted learning outcomes. Thus, implementation of OBE is a significant challenge for educators in the engineering field. Changes in curriculum development, the evaluation process and teaching approaches emphasise the need for a comprehensive change in the curriculum for engineering programme delivery methods. Changes in delivery methods are not limited to tutorial classes, they should also include laboratory experiments, final-year projects and other learning activities.

![Fig. 1. OBE curriculum development versus traditional approach.](image)

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![Fig. 2. Development of OBE curriculums.](image)

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2. History and Concept of the Integrated Project

Along with BEM requirements for accreditation, the curriculum in the Department of Chemical and Process Engineering (JKKP) turned to the OBE approach from the first semester of 2005/2006 session [4]. This approach requires students to take an active role in the learning process and also requires innovation and creativity from the higher learning institution to adapt their delivery methods, such as problem-based learning, project-based learning, active learning, cooperative learning and others [5-9]. Ensuring a comprehensive approach to the design and delivery of the curriculum is challenging for engineering education due to the curriculum being designed in separate stages and delivered through specific, discrete courses. The Institution of Chemical Engineers, UK (IChemE) has suggested that design should be introduced to the students from the beginning, not only in the final year [1]. To meet the accreditation requirements of BEM and IChemE recommendations, JKKP took the initiative to implement an IP which was exposed to an OBE approach for second-year students of the 2006/2007 session [10-11]. Since the 2010/2011 session and the implementation of the new curriculum, IP has been implemented with first-year students JKKP students, thus they can be trained gradually before facing the final-year design project. Up to the 2014/2015 session, eight cohorts of JKKP students have already been through the full IP cycle.

2.1. Historical background of the integrated project

There are several factors that contribute towards IP implementation. For chemical engineering students, project design (Project Plant Design Process) is compulsory in the final year of studies. This design is a project that combines the theory and understanding from the first-year students to the fourth-year students’ courses. The IP introduced by JKKP imitated this project design, however the difference is that it combines theory and student understanding that has been gained gradually by focusing on a limited number of courses in a particular semester. During the period before implementation of OBE in JKKP, in late 2004, almost all lecturers required students to complete individual projects for each course. This was a burden for the students to have to complete three or four projects simultaneously depending on the number of courses taken in a semester. As a result, students were weighted down with large assignments which they needed to submit at the end of semester as well as having to prepare for their oral presentation. Therefore, the introduction of IP reduces the burden for students because they only need to focus on the one IP project, which combines three or four department courses in a semester and is coordinated by one lecturer, which is easier to manage.

The idea of IP emerged after a final-year student made a proposal during an e-graduation ceremony in 2004. The e-graduation ceremony is traditionally held by the JKKP lecturers in the last semester of the fourth-year students, as a platform to gather their views and feedback for the purpose of the programme improvement. The final-year students had appreciated their experience of the plant design project even though they were unfamiliar with the wide scope of the project. The next factor that contributes to the formation of IP is integration theory and understanding. This is due to the fact that learning on a course is
often viewed in isolation and thus fails to link the theory gained between different courses.

2.2. IP implementation

IP carried out in groups ensures students become more innovative, proactive, and engage more in critical thinking and learning in making decisions while being able to justify their actions based on reliable and quality information. To facilitate IP implementation, one of the course lecturers is appointed as coordinator. The duties of the IP coordinator include: setting up a discussion among lecturers involved to determine the IP title, formation of small groups (4–5 students per group), giving details information about IP implementation to students, providing schedules for oral presentations, conducting reviews and recommendations at the end of semester.

Each course lecturer will introduce the course syllabus in the 1st week of each semester including brief explanations of course content, learning outcomes (LO) and methods of measurement and evaluation. Traditional lectures in the classroom, which are interspersed with class tutorials, quizzes or tests, take place during the first 10 weeks. In the 1st week, the IP coordinator will brief students on the details of the IP assignments and group allocation. For third-year students, a project title is not given, instead the students are asked to propose project titles based on the requirements of each course involved. They need to submit their title proposal to the coordinator in the 2nd week. Students are first introduced to the use of design software such as iCON® and SUPERPRO® in the second year since exposure at too early a stage is less effective for them. Third-year students are formally introduced to design software in courses such as computer-aided design and plant operation since the exposure in just the second-year students would be insufficient. In order to avoid students delaying their work until the last minute, they are required to submit a preliminary report in the 8th week lectures. Two weeks later, all the lecturers provide comments on the students’ draft reports and the students then have the opportunity to make corrections and re-submit before the presentation day.

3. Measurement Methods

In evaluating the effectiveness of IP, two approaches are used; direct and indirect measurements. Both approaches are based on measurements of six programme outcomes (PO: PO1, PO2, PO6, PO8, PO11 and PO12), which are set to be achieved through IP. The understanding and application of the theories and principles derived from each course is measured by PO1. The students’ ability to communicate orally and in the form writing is determined by PO2, while the level of cooperation among group members and their ability to manage the IP smoothly is evaluated by PO6. The students’ ability to develop positive characteristics of lifelong learning in order to determine resource quality is evaluated by PO8; the students’ skills to identify current issues related to IP is measured by PO11 and the students’ skills in using modern software to help solve the IP is evaluated by PO12.
3.1. Direct measurement

Direct measurement involves formal assessment by a lecturer that is made directly on the student’s performance in terms of oral presentations and technical reports, as well as through peer reviews by group members. For direct measurements, 80% of the total mark comes from lecturer assessments and 20% from peer reviews. The analysis of all evaluation criteria is based on nine POs, namely PO1, PO2, PO3, PO5, PO7, PO8, PO10 and PO11; PO6 will be evaluated by the students themselves since they are the most qualified to assess levels of cooperation between the group members. All students are required to evaluate their own group members through the PO6 assessment.

3.2. Indirect measurement

As well as direct measurements, students will be given a questionnaire at the end of IP implementation for a review and feedback session to acquire the students’ responses and feedback indirectly to the IP implementation. This questionnaire is divided into two main parts. The first part focuses on the student’s background in terms of gender, race, and programmes taken. The second part contains statements that refer to the achievement of the nine POs (PO1, PO2, PO3, PO5, PO6, PO7, PO8, PO10, PO11) when students performed the IP. The statements refer to the application of basic knowledge, analytical and problem solving (PO1, PO2 and PO3), use of software VISIO®/AutoCAD® (PO5), identification of current issues (PO6) sustainability (PO7), engineering ethics (PO8), communication (PO9), teamwork (PO10) and lifelong learning (PO11).

In addition, students’ views about whether the IP implementation should be continued or otherwise are gathered. Students were asked for suggestions for improvement or any comments on the IP implementation. It is common practice in JKKP, at the end of each semester, to give students the opportunity to share their feedback for improvement purposes on the teaching and learning activities in the department, whether about course registration, lectures and facilities and infrastructure. Approximately about 24 students were selected by the department based on their cumulative grade point average (CGPA) (weak, medium and good) for each year study to attend this feedback session. Within this session, students were asked about various aspects of the IP implementation. They are able to share any problems they faced or suggest any improvements for IP that could be considered for the next cycle of students. Besides this feedback session, JKKP also organized the e-graduation ceremony for students who were to graduate at the end of session. Similar to the feedback session, the students gave their feedback on the programme they had completed over the previous four years, including giving their views on IP implementation. Through this dialogue and the graduate ceremony, positive views and comments are often obtained from final-year students. Students feel that IP is invaluable in assisting them in plant design project, and suggested that IP should be continued in the future [11].

4. Results and Discussions

The JKKP always sought to assess the effectiveness of the IP achievement and performance of its students, based on the nine POs. Each semester, the IP
coordinator makes comparisons between the evaluations of lecturers and students measured directly and indirectly through student feedback obtained through questionnaires at the end of semester. Figures 3-7 show examples of comparative analyses that have been made in order to measure between the first-year, second-year, third-year and fourth-year chemical (KK) and biochemical (KB) students that have been through IP in the second semester 2013/2014 [12]. For direct measurements, the scoring is displayed in the form of a percentage mark given by lecturers while the feedback obtained from the students’ questionnaire is presented according to students’ agreement with statements relating to the PO involved. For comparative purposes, the questionnaire results were converted into scores or percentage points as in the direct measurement.

4.1. Analysis of PO

Figures 3(a) and (b) show a comparison of PO achievement between direct and indirect measurements for first-year KK and KB students respectively. The student assessment for achievement of PO1, PO2, PO3 (basic knowledge, analytical and problem solving), and PO10 (teamwork), is higher (90%) than the students’ evaluation through questionnaire (80%). The same trend is seen for PO7 (sustainability) achievement through direct or indirect measurement. Though the achievement of PO6 (identification current issues) and PO8 (engineering ethics) show some gaps between the lecturers’ and students’ evaluations, the average is 60–75%. For PO11 (lifelong learning) achievement, the student assessment (73%) shows a big gap and much greater than the student evaluation (43%).

![Fig. 3. Comparison of PO achievement between direct and indirect measurement for First-Year Chemical Students (a) and Biochemical Students (b) respectively.](image)

All POs (PO1, PO2, PO3, PO9 and PO11) achieved the target percentage of above 80% both by lecturer evaluation (direct measurement) and student assessment (indirect measurement). For the PO10 (teamwork) analysis, both the direct and indirect measurement is done by the students. The direct measurement of PO10 is the student evaluation of their team members after finishing their oral presentations, (which contributes 20% of the total IP mark).
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is obtained through a student survey of their peer group. Due to the ‘generous’ nature of students most give full marks to their group members. However, the student questionnaire has nothing to do with the assessment, thus feedback is more transparent and therefore credible. Consequently, the PO achievement evaluated through questionnaire is lower than the peer assessment. The same pattern is also obtained for the achievement of PO2 (70% of students; 82% of lecturers) related to the use of modern computing software. Lecturers give higher marks than student evaluations due to their differing expectations where the students do not think that their exposure to the software is sufficient and would like it to be taught directly and in much greater detail by the lecturer.

The PO achievement for first-year KB students shows no significant observed variance between the lecturer evaluation and student assessment for PO1, PO2, PO3, PO6, PO7 and PO10, with the exception of PO8, PO9 and PO11. All POs (PO1, PO2, PO3, PO6, PO7, and PO10) achieved the target percentage of 80% either through lecturers’ or students’ evaluations in all six categories, where the scoring was between 80–85%. For PO8 (engineering ethics) and PO11 (learning lifetime) achievement, the direct measurement (74–83%) is higher than the student evaluation (43–63%). On the other hand, PO9 (communication skills) achievement shows that student assessment (81%) is slightly higher than the lecturer evaluation (74%).

The PO achievement of second-year KK and KB student is shown in Figs. 4(a) and (b) respectively. Similarly, there are no significant differences observed between the lecturers’ and students’ evaluations of achievement of PO1, PO2, PO3, PO6, PO7, PO9, PO11, and PO10, with the exception of PO8. All POs (PO1, PO2, PO3, PO9 and PO11) reported achieving the target percentage of about 80% either by lecturers’ or students’ evaluations. Though the results for PO10 (teamwork) by direct measurement (95%) is higher than the student assessment (80%) because the students felt there were some members in their group who did not complete their assignment and unable to give full cooperation to the group.

![Fig. 4. Comparison of PO achievement between direct and indirect measurements for Second-Year Chemical students (a) and Biochemical students (b) respectively.](image)
The PO achievement of third-year KK and KB students is shown in Figs. 5(a) and (b) respectively; a small difference was found between lecturers’ and students’ evaluations of achievement of PO1, PO2, PO3, PO6, PO7, PO8, PO9, and PO11, with the exception of PO10. All POs (PO1, PO2, PO3, PO6, PO7, PO8, PO9 and PO11) achieved the target percentage of 80% either from the lecturers’ or students’ evaluations. The results for PO10 (teamwork), show the student evaluation through questionnaire (99%) is much higher than the student assessment (65%). This clearly shows the cautiousness of students or their ‘generosity’ may be more evident when most of the students give full marks to their group member to avoid any negative impact on their final grade. However, as the questionnaire has nothing to do with scoring, the feedback provided through the questionnaire is more transparent and credible. Therefore, the assessment through questionnaire is lower than the student assessment.

![Fig. 5. Comparison of PO achievement between direct and indirect measurements for Third-Year Chemical students (a) and Biochemical Students (b).](image)

The PO achievement of third-year KB students also shows the same trend. All POs achieve the target percentage of approximately 80% either from lecturers’ or students’ evaluations except for PO10 (student evaluation). The result for PO10 (teamwork) for the student assessment (94%) is higher than the evaluation by students through the questionnaire (65%) on the same grounds as the KK students. Overall, although there are some differences between the direct and indirect measurements, however the difference reported in the above figures are too small.

Figure 6(a) shows the comparison of PO achievement among first-year, second-year and third-year students through direct and indirect measurements. It was found that all POs showed an increase in percentage from the first-year to the third-year of study, except for PO10 (teamwork) where there was a decline shown from the second-year to the third-year of study. This may be due to students feeling pressure due to the group member who fails to cooperate in completing the IP. Yet, PO11 (learning lifetime) shows the highest PO achievement from the first-year to third-year, where the students feel that exposure to IT, computer software and writing techniques have enabled them to produce high quality IP.
Achievement of Programme Outcomes through Integrated Project as of previous years. Overall, not only do students feel IP is useful and beneficial to their learning process, the lecturers too. The effectiveness of IP from its implementation in semesters 2006/2007 to 2013/2014 is also investigated through questionnaires completed by JKKP lecturers and final-year students. The comparison of PO achievement between fourth-year students and lecturers through direct and indirect measurements are shown in Fig. 6(b). There are no significant differences observed; a small difference was found on the achievement of PO1, PO2, PO3, PO5, PO6, PO7 and PO9, but not in PO8, PO10 and PO11.

![Fig. 6. Comparison of PO achievement among First-Year, Second-Year, Third-Year (a) and Fourth-Year Students and Lecturers (b) through direct and indirect measurements.](image)

All POs accomplished the target achievement percentage of about 80% either by lecturers’ or students’ evaluations except for PO8 and PO11. The PO8 (engineering ethics) and PO11 (lifelong learning) achievement was under 60% both by lecturers’ or students’ evaluations. This was due to the students’ difficulty in finding references and reading materials on the Internet or other sources as well as a lack of exposure to the use of IT, no skills in data analysing and a lack of skills in writing technical reports. Also PO10 (teamwork) by lecturer evaluation (92%) is higher compared with the students’ assessment (70%). This shows the lecturers are more satisfied with student teamwork compared with the students themselves who experienced first-hand the attitudes and levels of cooperation there were among group members.

There are five parts to the questionnaire, where Part A is about student background, Part B asks about IP implementation, Part C describes the IP contents, Part D is about generic skills that are acquired by IP and Part E covers disclosure and use of software in the IP. Overall, both KK and KB students show that IP achievement. There is a gap between direct and indirect measurements, however the difference in scores are very low. Sections C and D recorded the highest percentages compared to other parts. This shows the students felt IP had successfully helped them to understand and strengthen the basic concepts of chemical and biochemical engineering, had exposed the students to the concepts and practises of sustainability while helping students to understand the current issues related to the engineering field and
teach students to analyse and interpret the data, thereby providing a critical view of an issue.

In addition, PO achievement for both KK and KB students were also compared to the four previous cohorts of students, as shown in Fig. 7. The students were asked about the learning outcomes since their first-year of study for educational achievement, preparation for a career, relationships between students and lecturers, and facilities in the department. From the analysis, the increase from year to year on student achievement and performance is shown, however there is also a percentage decrease shown for the 2013/2014 session. This is probably due to several problems involving insufficient numbers of computers and software. However, overall both chemical and biochemical student achievement accomplished about 70% of the student evaluation based on the results of the questionnaires.

4.2. Process improvement

During the eight years of IP implementation in JKKP, there have been many process improvements instigated by the lecturers or the students themselves. All the improvements that have been made have been based on the feedback given by final-year students, as shown in Table 1, either through review sessions, questionnaires or session dialogues, and through assessment programmes [13-14]. The improvements made include introducing the preliminary report which students need to send during the 8th week to ensure students have started their project sufficiently early. Previously, lecturers’ observations reported how students often delay their work until the last minute. Furthermore, in order to take an action against any ‘sleeping partner’ within the group, the IP coordinator always emphasised the need for each group to make a complaint at the beginning of the semester rather than wait until the last minute if there are any group members who fail to cooperate. Thus, lecturers deducted group marks for an individual member.
Table 1. IP problems and ways to improve them.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working last minute</td>
<td>Submitting the preliminary report at week 8</td>
</tr>
<tr>
<td>Team member evaluation</td>
<td>Avoid ‘sleeping partner’</td>
</tr>
<tr>
<td></td>
<td>Increased team member evaluation from 10 to 20%</td>
</tr>
<tr>
<td>Distribution group</td>
<td>Opportunities for students to form their own group</td>
</tr>
<tr>
<td></td>
<td>Group changed from one semester to another semester</td>
</tr>
<tr>
<td>Parallel session</td>
<td>Presenters selected randomly</td>
</tr>
<tr>
<td>Students’ weakness / repeat</td>
<td>Keep repeating IP although not register for all courses</td>
</tr>
<tr>
<td>Too little exposure to iCON / SUPERPRO</td>
<td>Students are given early exposure by PETRONAS instructor</td>
</tr>
<tr>
<td></td>
<td>Students should have the initiative</td>
</tr>
<tr>
<td></td>
<td>Lecturer trained with ICON / SUPERPRO simulators</td>
</tr>
<tr>
<td>Students do not meet lecturers</td>
<td>Hold a log book – the appointment of a group leader, log</td>
</tr>
<tr>
<td></td>
<td>and record minutes meetings</td>
</tr>
<tr>
<td>Difficult to meet lecturers</td>
<td>Each lecturer allocates a specific time to meet the IP group</td>
</tr>
<tr>
<td>Lecturer concerns about IP</td>
<td>IP becomes fixed in the department meeting agenda</td>
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</tbody>
</table>

5. Conclusions

IP was established and implemented at JKKP, Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia in order to satisfy BEM accreditation requirements. Students are the main stakeholders in the short and medium term IP implementation. The students’ feedback mechanisms that have been implemented, namely course assessments, student dialogue sessions and exit surveys, despite concerns on their effectiveness, are able to gather relevant feedback from the students and help to promote future improvement. The improvements that have been introduced are highly regarded by various stakeholders. However, existing mechanisms for gathering students’ feedback need to be improved further to enhance their effectiveness.

References


