Engaging engineering students in early stages by design projects

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Abstract

Engaging the students by a design project is a fundamental activity for any engineering degree programme as it promotes in depth the circulation of skills and transferable knowledge through solutions that meet the learning outcome requirements of programme accreditation institutions. Literature is rich in works on the final year capstone design projects where the students are encouraged to demonstrate their engagement for innovation by undertaking open ended activities but remains less explicit on design projects at the early years of the curriculum where the transferable knowledge remains under development may be seen not sufficient to undertake effectively open ended projects with independence in decision making and leadership. This work introduces experience of education practice of the second-year chemical engineering design project through two distinct models: problem-based learning and project-based learning using two case studies: waste tyre gasification into energy and methanol production from syngas, respectively. The former model requires the students to investigate the pathway to reach solution using prior knowledge and the later requires the students to focus on the final solution. The results in terms of effectiveness of leaning and engagement revealed that both methods were seen by the students effective in promoting teaching and developing the design skills. The cognitive learning by students' engagement was more in favour of project-based learning that offered less uncertainties in the final results and promoted feedback by the students.

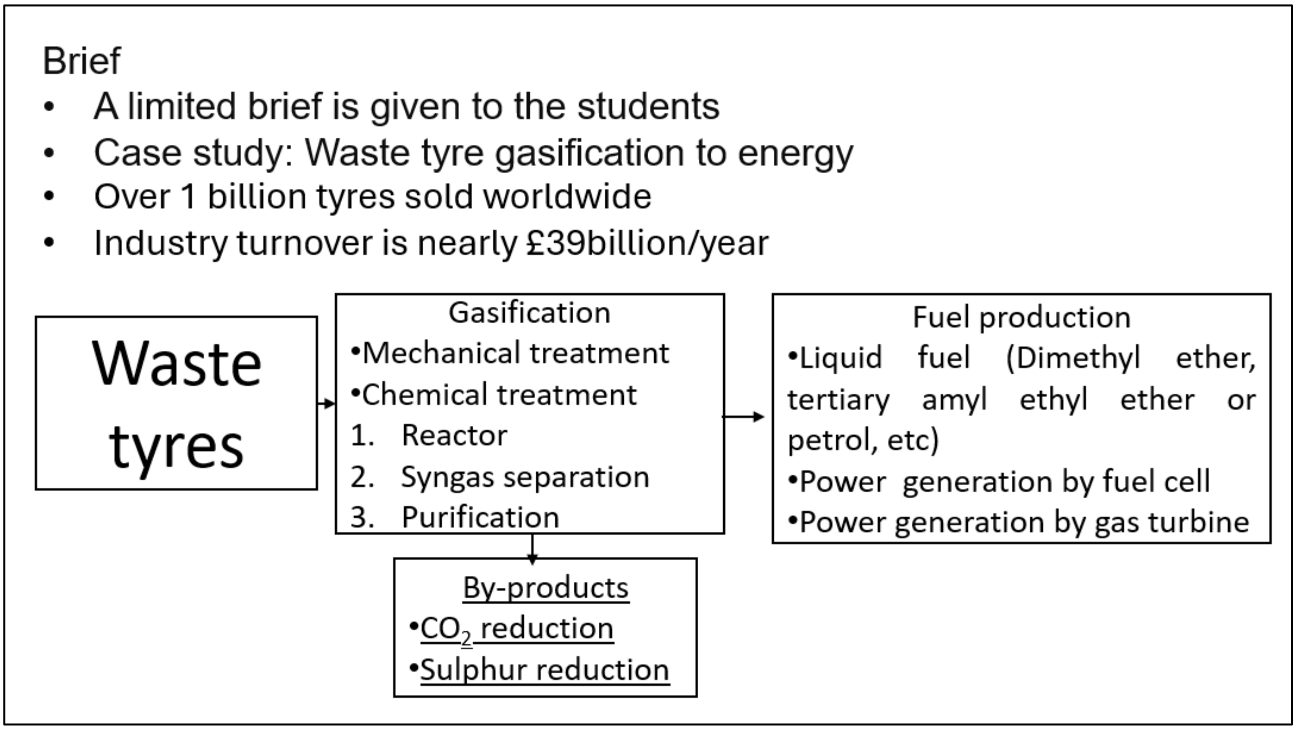
1. Introduction

Students in engineering programmes are required to be involved in group design projects that are viewed by them among the most exciting parts of the curriculum, offering opportunity to engage, with some level of independence, knowledge whilst undertaking coordinated group activities in a creative way that reproduce the real-world practices (Kiss and Webb, 2021; Felder, 2004). The students are given opportunity of some level of independent to leaning by working in groups and develop projects into basic specifications for the products (Dhanasekaran, 2023). The learning by design projects fosters students' engagement with their learning context and mitigates the passivity observed often in lecture-based learning. There is an extensive literature on students' engagement by the capstone design of the engineering final year which uses fundamentally problem-based learning (ProbBL) model but less literature, to nearly non-existing literature, is available on learning approaches at early stages of curriculum in engineering education where the subjects of modules are not sufficiently covered to undertake open ended studies, which in turn impacts level of independence in decision making and leadership to undertake a design. Open ended approach facilitates development of creative problem-solving skills for engagement by design and intuition with no obvious single correct answer and the constructive working guidelines improve definition of the project goal, task understanding, planning and monitoring (Alejandro et al., 2023) but they remain not straightforward at the early years of curriculum to support the design skills (ie. motivation, leadership, solving design problems, communication, organisation, solving inter-personal problems and collaboration).

Along with the engagement by ProbBL model, there are other approaches of learning for students' engagement that are also centred on the students by development of pedagogical schemes that includes inquiry learning, project-based learning (ProjBL), collaborative learning, digital -based environment and team-teaching (Hutchings and Quinney, 2015). Unlike the ProbBL model which requires the students to investigate, solve problems of the design using prior knowledge, proceed with more open ended and ill-structured learning, as discussed by Curtis and Ventura-Medina (2007), the ProjBL model requires the students to engage in a design of a product and focus on the final solution than the process to reach it. This work was developed based on experience of education practice to measure students' engagement in the second-year chemical engineering design project through two leaning methods: ProbBL model and ProjBL model using two case studies: waste tyre gasification into energy and methanol production from syngas. The means by which ProbBL or ProjBL these skills can be used to extend student engagement are discussed.

2. Methods

The design project in chemical engineering is compulsory module given to approximately 40 students on annual average placed into 10 to 15 groups of 3 to 4 students. Each group is allocated similar brief and support by means of a combination of in-class lecture sessions for activities lectures, brainstorming and organisation and outside classes for activities of deep learning. Two types of leaning illustrated herein by two cases studies: ProbBL and ProjBL practiced over two years and three years, on waste tyre gasification into energy and methanol production from syngas, respectively, are discussed in terms of learning effectiveness and student engagements. The briefs of both case studies are illustrated in Figures 1 and 2. The students were engaged to support an adaptation of learning to students of various capabilities and culture by arranging student groups based on their abilities, wishes or random distribution. The later arrangement was adopted as they see it more realistic to reproduce the workplace environment without omitting the differentiation of engagement and leadership skills, often addressed by role assignments and assessments.



Brief

- A limited brief is given to the students
- Case study: Waste tyre gasification to energy
- Over 1 billion tyres sold worldwide
- Industry turnover is nearly £39billion/year

Figure 1: Case study 1: Waste tyres gasification into energy by ProbBL

(a)

Brief. The design of a chemical plant to produce 75000,00 tonnes per year of methanol by the catalytic reaction of synthesis gas containing carbon monoxide and hydrogen that were obtained by the partial combustion of a hydrocarbon stream (paraffins).

1. Process description

A stream of mixed paraffins containing 1 % sulfur is fed, along with a steam and oxygen, into a pressure vessel where partial combustion takes place, producing a mixture of carbon monoxide, carbon dioxide and hydrogen. Assuming the average heat of the reaction (ΔH_r, enthalpy) = 600 x 10^3 kJ/kmol of paraffins. A solution of an aqueous solution of Monoethanolamine (MEA) of 20 wt. % and 80 wt. % water is used to absorb 90 % of the carbon dioxide. Assume that the solution is sufficient to absorb all the entering H_2S (small concentration) no other gases are absorbed. Assume the saturated vapour pressure of water at 50ºC is 0.1233 bar, the evaporation of the solvent MEA is assumed negligible and the solubility of CO_2 in MEA is 0.6 kmoles of CO_2/kmoles MEA. After cooling and scrubbing to remove sulphur compounds, the gas mixture is compressed to 20 and 30 MN/m^2 and is passed to converter. This contains a zinc-chromite catalyst arranged in about three layers with inter-stage cooling. At the operating temperature of 620 K, the following reactions occur:

(i) $CO + 2\,H_2 \leftrightarrow CH_3OH$ extended to the chemical equilibrium conversion,
(ii) $2\,CO + 4\,H_2 \rightarrow C_2H_5OH + H_2O$ extended to 10 % reaction conversion
(iii) $CO_2 + H_2 \rightarrow CO + H_2O$ extended to 60 % reaction conversion
(iv) $CO_2 + 4\,H_2 \rightarrow CH_4 + 2\,H_2O$ extended to 40 % of reaction conversion

The gases leaving the converter are cooled and the crude methanol is separated by condensation. Part of the unreacted gas is purged from the system to remove inert gases, and burnt, while the remainder is recycled to the converter by a circulating compressor. The crude methanol is purified by flash distillation at 4 bars and column distillation to remove the by-products, mainly ethanol and water.

Assume equilibrium constant of reaction (i) $K_p = \frac{490}{T} - 9.1293 \log_{10}T + 0.0030T + 13.412$

2. Feed description

The hydrocarbon stream is assumed equivalent to a mixture containing 80 % methane by volume at atmospheric pressure, the balance being ethane 15 % and propane 5 %. Oxygen is available as required from an air liquefaction plant and assumed 100 % pure.

3. Product specification: Th purity of methanol is required at non less than 99 wt %.

4. Utilities: Steam: dry saturated at 10 bars, Temperature of the cooling water: 293 K, Temperature of process water: 293 K andElectricity: 440 V, 50 Hz, 3 phase

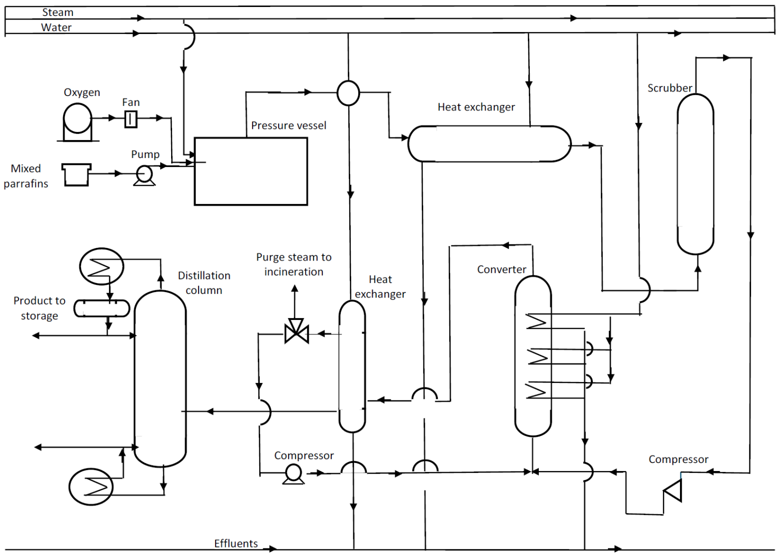


Figure 2: Case study: Production of methanol from synthesis by ProjBL, (a) brief description and (b) Process Flow Diagram

3. Results

3.1 Students' narrative feedback

Two selected narratives from students' feedback on the most valuable parts of the module, are literally reproduced : "..The module is seen hard, high workload for a week module, hard for a student to figure out what to do as part of the team" and "… more clear instruction list so students know what they're actually doing”. The feedback confirms the typical challenge associated with the problem-based learning to identify the problems for design solutions with insufficient prior knowledge in the subject of chemical engineering programme, confirming observations by Zhang et al. (2022). The narrative of one student however for case study 2 was: “… the lecturer believed we had a lot of knowledge prior to this module, but I personally don't feel that we had enough preparation”, which confirms that project based learning, while it provides detailed instructions, raises the challenge the expectations to develop accurate final solution to the design which is seen challenging by the students.

3.2 Students’ quantitative responses

Illustrative feedback following the completion of design of both cases studies to measure the teaching practices is shown in Figure 3 and Figure 4. Figure 3 shows the responses on the promotion of the engineering design skills (ie. motivation, leadership, solving design problems, communication, organisation, solving inter-personal problems and collaboration), based on a 5-point Likert-scale (‘1' meaning ‘disagree’ to 5 meaning ‘agree’) and obtained over the academic years (AY) 2 and 5 of teaching practice and relevant to ProbBL and ProjBL, respectively. The promotion of these skills was agreed by a proportion of students varying from 35 to 70 %, which increases to 85-95 % when partial agreement is counted. It is seen by the students that leadership skill was highly improved (~79% agreed), followed by solving design problems, organisation, and collaboration (~50 % agreed), motivation (~ 40 % agreed) and solving inter-personal problems (35 % agreed). The trends of both types of learning, ProbBL and ProjBL, are not much different, including the feedback relevant partial and full disagreements (~15 % disagreed).

Figure 4 illustrates students’ feedback on three questions: “engagement”, “learning” and “intellectual challenge” applied to both types of learning (ProbBL in AY2 and ProjBL in AY3, AY4 and AY5) and measured over a scale 1-5 (1: poor and 5 outstanding). The ProbBL was seen more effort demanding as the students had more independence but faced more challenges to find pathways to the solutions compared to the ProjBL (AY3-AY5). The students felt they learnt a lot from both types of learning with exception to AY 3 which would be interpreted by the transition between the two types of learning. The students reflected that the module taken over ProjBL was more challenging which confirms the narrative feedback.

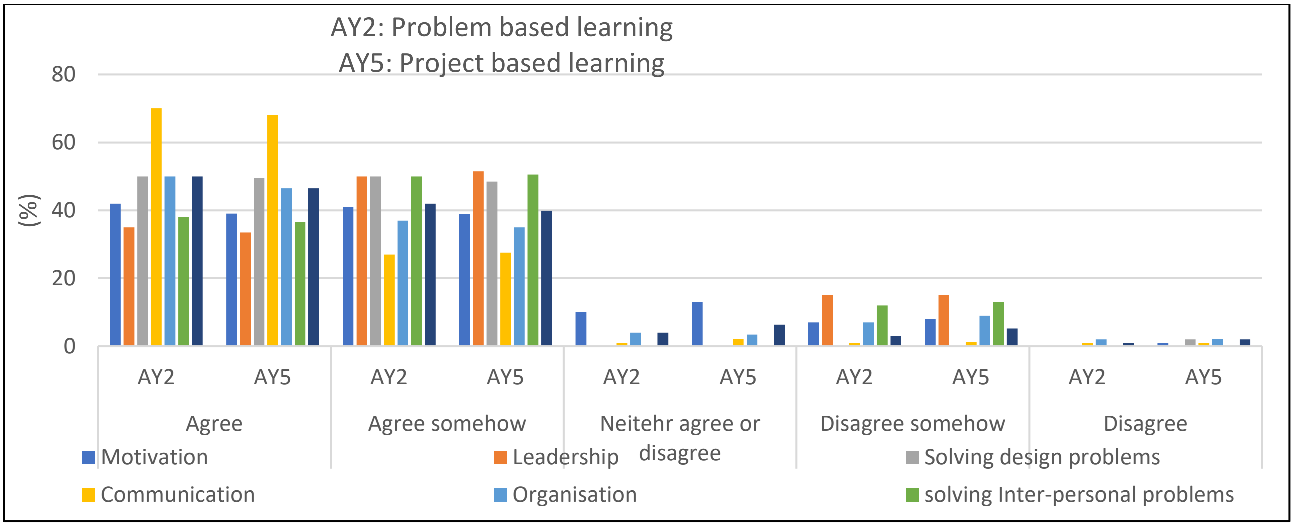


Figure 3: Students' feedback on promotion of the engineering design skills

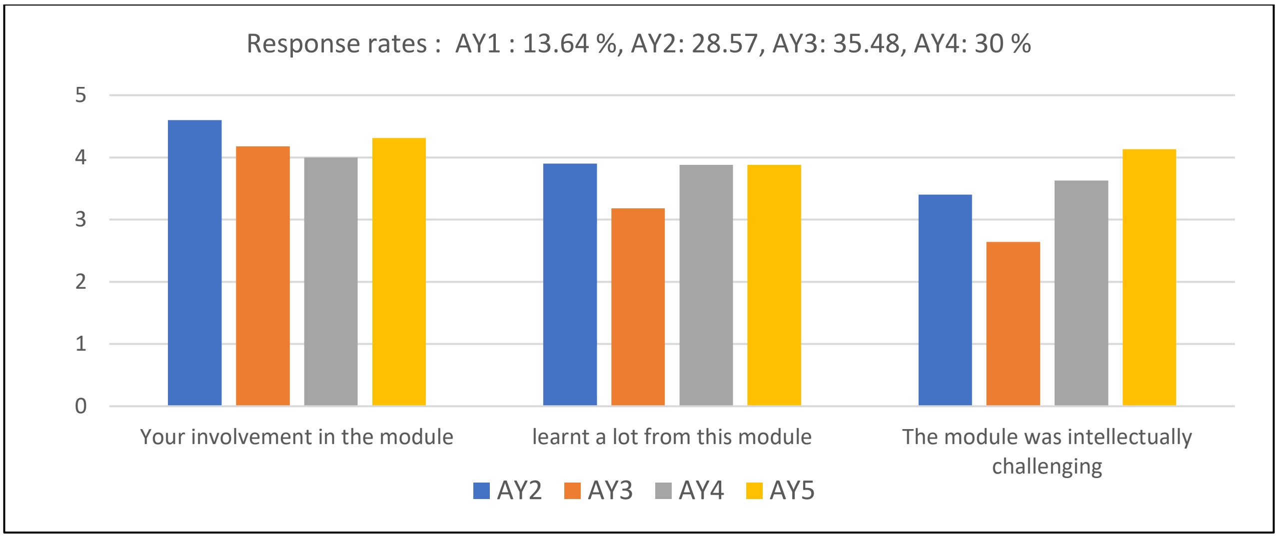


Figure 4: Students' feedback on engagements

While the ProjBL offered options of close support, it required advanced conceptional design combined with reduced uncertainties in the results of the design in comparison with ProbBL design where the students spend much of the effort in the solution to the design. Despite the statistical limitation of the study, it can be drawn from both figures that the students primarily felt that both teaching styles were effective at supporting development of their engineering design skills.

4. Conclusion

The students were induced to open ended design projects with inter-connected learning practices constructed on prior knowledge, helping improvement of retention of core knowledge to comply with the professional standards of engineering education. The students were asked over a minimal brief to undertake a conceptual design, development of core and communication performance. The two methods of leaning based on ProbBL and ProjBL were seen effective by the students while the former was perceived more effort demanding and less challenges to find solution to design problems with reduced uncertainties. However, the context was relevant for the cognitive learning by students' engagement which was more in favour of ProjBL model that offered less uncertainties in the final results. The later was an important factor for students' performance when the summative assessment is associated. The outcome of this work is observed in the teaching of this project design module using ProjBL approach which has been adopted in the years that followed this work by the school of engineering.

References

Richard M. Felder, R.M. (2004). Teaching engineering at a research university: problems and possibilities. *Educación Química*, 15(1), 40-42

Dhanasekaran, P.S. (2023). The Role of Project-based learning in first year engineering. *Fall Mid Atlantic Conference, ASEE. 27 October 2023*, Paper ID #40828

Hutchings, M., Quinney, A. (2015). The Flipped Classroom, Disruptive Pedagogies, Enabling Technologies and Wicked Problems: Responding to "The Bomb in the Basement". *The Electronic Journal of e-Learning*, 13(2), 106-119

Moure Abelenda, A., Aiouache, F., Moreno-Mediavilla, D. (2023). Adapted business model canvas template and primary market research for project-based learning on management of slurry. *Environmental Technology & Innovation*, 30, 103106

Curtis, R., Ventura-Medina, E. (2007). An Enquiry-Based Chemical Engineering Design Project for First-Year Students. *Chemical And Process Engineering, CEEBL Supported Project 2006-7*

Kiss, A., K and Webb, C. (2021). The Manchester perspective on using the Design Project to enhance the education of chemical engineering students, *Journal of Chemical Technology & Biotechnology,* 96, 1453–1464

Zhang, J.M., Croiset, E., Ioannidis, M. (2022). Constructivist-based experiential learning. *Education for Chemical Engineers,* 41, 22–31