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## Integrated Project as Innovative Assessment to Enhance Learning Experience in Thermodynamics Class

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### ABSTRACTS

An integrated project is introduced to students to relate the concepts and equations taught between courses in the same semester. It also helps students in managing allocated time for assessments and collaborating among them, which eventually enhances their learning experience, especially for thermodynamics courses. In this case, the integrated project was done by relating two courses: Chemical Engineering Thermodynamics 2 and Separation Process 1 for Year 2 students. The methanol production plant was chosen as a model case, where students need to simulate the vapor/liquid equilibrium in the purification unit using HYSYS simulation software. Overall, students show highly positive sentiments upon the projects, in which more than 90% of them think that the project helps them to understand the coursework materials and prepare for other assessments. The majority of students want to experience the same type of project in the future, and it helps to save their time rather than working on separate projects. The project also exposes the students to set skills related to technical competence and soft skills that could build their characters.

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## 1. INTRODUCTION

Thermodynamics teaching is closely related to the energy transfer, work, temperature, and their relation with the process in a system. The principles of thermodynamics are related to many energy systems such as refrigeration, power plants, and also chemical processes (Mulop *et al.*, 2012). For chemical engineering students, thermodynamics is a core subject and quite challenging to comprehend, as stated in previous studies, which can lead to the misconception (Baran & Sozibilir, 2018; Mulop *et al.*, 2012). Since outcome-based education is adopted, the shifting of the teaching and learning process is strongly going towards student-centered active learning (Ballesteros *et al.*, 2019).

Innovative assessment can be introduced as a method to improve the learning experience of students, which eventually improves their understanding of the subject, especially through project-based learning. Project-based learning attracts students to use their skills by organizing them in small groups with minimal guidance and contextualizing real problems (Baran & Sozibilir, 2018). On a smaller scale than project-based learning, the integrated project has been applied to improve the participation of students in the learning process and develop collaborative work among the students, in helping them to face diverse environments (Trisdiono *et al.*, 2019). Besides, soft skills such as communication, critical thinking, and self-confidence of students have been found to improve as well (Sidik & Masek, 2021; Trisdiono *et al.*, 2019).

Throughout their study, many times students find it difficult to relate between the taught courses. By introducing integrated projects between Thermodynamics and Separation Process courses, students are expected to relate to the concepts and the equations between these courses in a chemical process, so they can see the knowledge as a whole. The design of process flow, mass balance calculation, and vapor-liquid equilibrium graphs construction from instruments designated to purify the product are addressed in this integrated project.

Through the integration of the integrated project in teaching and learning, students can visualize and approach the taught concepts in the class by using a real case study. During their discussion in a team, students can brainstorm ideas, negotiate on the possible solutions, and some can lead their peers (Antequera & Herrero, 2012; Ballesteros *et al.*, 2019). Hence, they can deepen their understanding through the activities related to the project (Ballesteros *et al.*, 2019). Additionally, students also need to integrate the simulation of constructing the vapor-liquid equilibrium graphs by using HYSYS simulation software. During the limited number of weeks (12 weeks) designated for teaching in a semester in Universiti Teknologi PETRONAS, the integrated project can be a beneficial tool to help the students in managing their time for assessments between all different classes that they take (Ballesteros *et al.*, 2019). The students' feedback and satisfaction upon the integrated project are assessed at the end of project implementation.

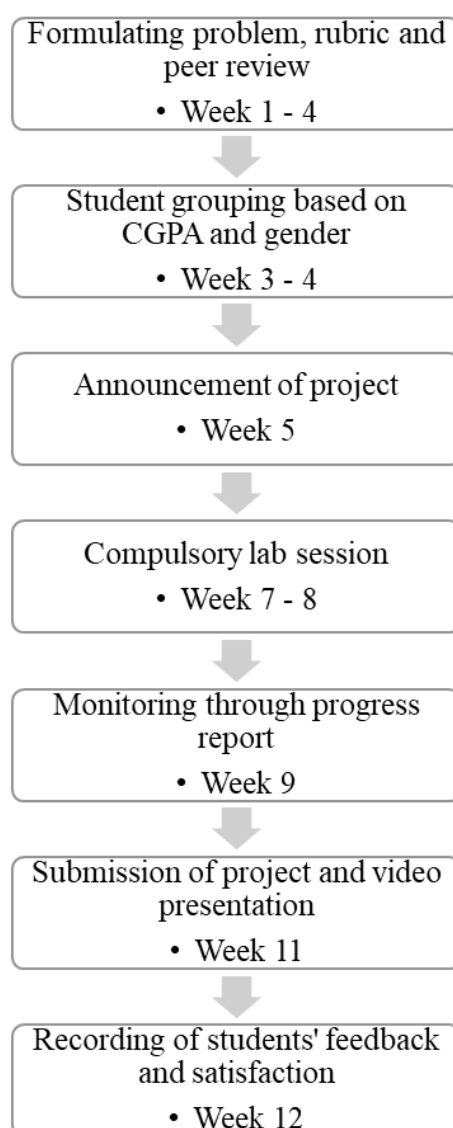
## 2. METHODS

The integrated project combines the projects for Separation Process 1 and Chemical Engineering Thermodynamics 2 courses for the 2nd-year students in September 2020 semester. A total of 175 students participate and are organized into 41 groups, in which each group consists of 4 – 5 students. The integrated project contributes to 15% of the overall coursework mark.

The methanol production process was used as the case study, in which students need to design the process according to the assigned purity of the product. The assigned tasks for students are listed as follow:

- (i) Provide an introduction to methanol.
- (ii) Propose suitable plant capacity with business/market analysis justification.
- (iii) Provide the selection of instruments for the methanol production process.
- (iv) Draw the process flow diagram of methanol production from natural gases by using appropriate software and describe the process flow in detail.
- (v) Use HYSYS software to generate the vapor/liquid equilibrium graph, construct the phase envelope, and predict the mole fraction of vapor over liquid, vapor composition, and liquid composition using flash calculation.
- (vi) Design the distillation column for the methanol purification unit.
- (vii) Submit a final report and provide 10 minutes or recorded video presentation.

The duration of integrated project completion is 7 weeks, and the processes of formulating the project, announcement, and submission are shown in **Figure 1**. To implement the simulation part in the project and improve the experience of students upon the software, students were subjected to compulsory lab sessions to learn the operation of HYSYS software. At the end of the project, students need to fill in the peer-review and questionnaires to record their feedback for this project.



**Figure 1.** Flow of integrated project implementation.

### 3. RESULTS AND DISCUSSION

The examples of solutions provided by students are shown in **Figure 2** for the process flow diagram and **Figure 3** for the HYSYS simulation results. Hence, the project introduces students to the drawing of the simple process flow diagram and conducting simulation related to the purification of methanol. These experiences are expected to equip them with a preliminary knowledge of chemical processes, before exploring it in depth during the capstone project in Year 4. Additionally, the introduction of the process flow diagram and HYSYS provide a framework to design problems for this integrated project, and students in Year 2 have enough time to gain moderate chemical engineering maturity to work on this project.

Based on the feedback provided by students, around 99.3% of students think that the project helps them to understand the coursework materials (**Figure 4a**), and around 93.6% of overall students think that the project helps them to prepare for a test or extended assignments (**Figure 4b**), which is a replacement of ordinary final exam in the form of open-ended questions based exam. Hence, from these results, students think very positively about the project, especially in improving their understanding of thermodynamics concepts and applications. The project covers the vapor/liquid equilibrium of binary mixture and calculation related to it by involving HYSYS as a simulation tool. HYSYS itself has been widely used to explore the simulation of thermodynamics concepts related to ideal and non-ideal mixtures (Lopez-Zamora *et al.*, 2021). Through this project, students can relate the concepts taught in class and HYSYS as simulation software can be used to produce the graphs related to vapor/liquid equilibrium variables such as the composition of liquid and vapor at different temperatures and pressures, as well as to perform the necessary calculation (**Figure 3**).

They emphasize the importance of teamwork and collaboration to provide solutions for this project is supported by 100% of students (**Figure 5a**). While 37.1% of students strongly agree, 59.3% agree and only 3.6% do not agree that the project saves more time compared to a separate project (**Figure 5b**). Hence, the project helps students to manage their time during the learning process in that semester. As stated in previous studies, working in a team for a project provides an opportunity to collaborate, discuss, share the knowledge and ideas that were integrated to provide solutions for the project (Ballesteros *et al.*, 2019; Trisdiono *et al.*, 2019). Hence, this positive experience will motivate them to work in a team in the future. This sentiment is supported by 80% of students that want to see this type of integrated project in the future. While 20% is still reluctant, which can be due to lack of freedom in choosing team members, since all groups are pre-assigned, and limited-time provided to complete the project.

The importance of teamwork is again emphasized in skills that students learned during the completion of the project (**Figure 6**). Students were asked to write down what skills that they have learned, and the collected answers were organized to show around six major sets of skills that appear on their answers: simulation software operation, drawing of process flow diagram, calculation technique, communication skill during working in a team, analysis of information, and preparing a good presentation. Around 3 sets of skills related to technical competencies, which are simulation software operation, drawing of process flow diagram, and calculation technique, with around 75.7; 50.0; and 37.9% students, respectively, think that they acquire the skills. On the other hand, other 3 sets of skills related to soft skills, which are communication skills during working in a team, analysis of information, and preparing the good presentation, with around 23.6; 46.4; and 22.1% students, respectively, think that they were exposed to the skills. Therefore, the project can address both technical and soft skills for students' competence, which can help them to mature intellectually and socially.

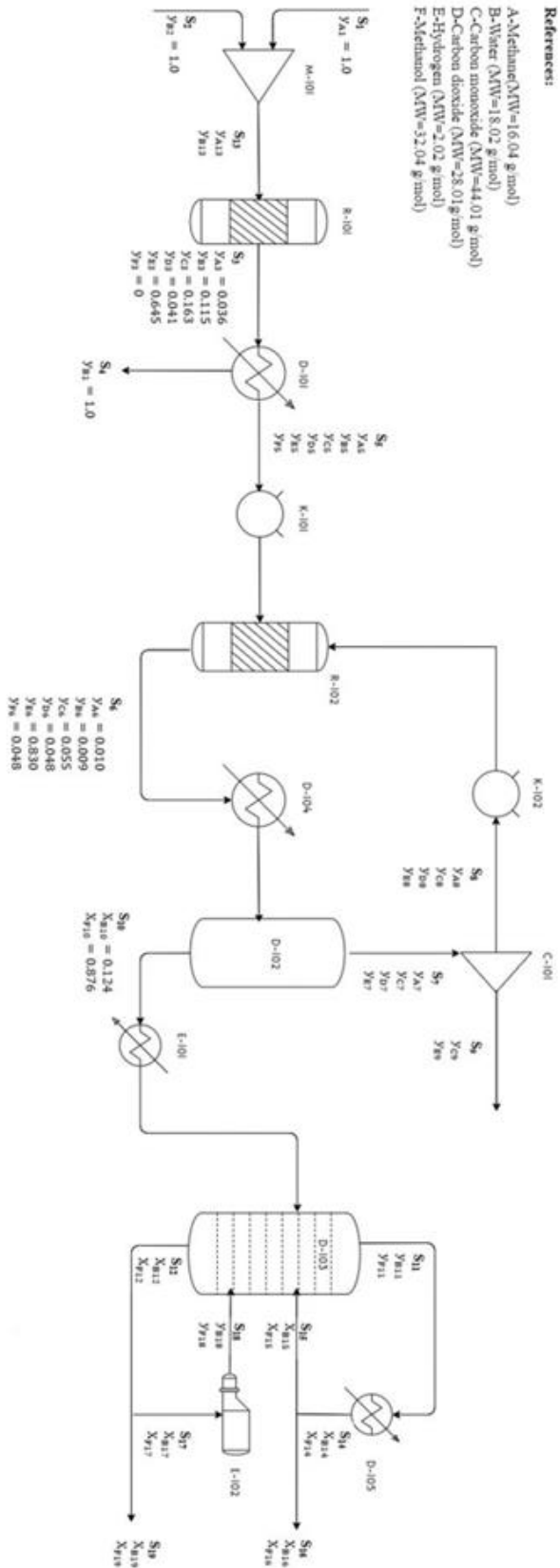
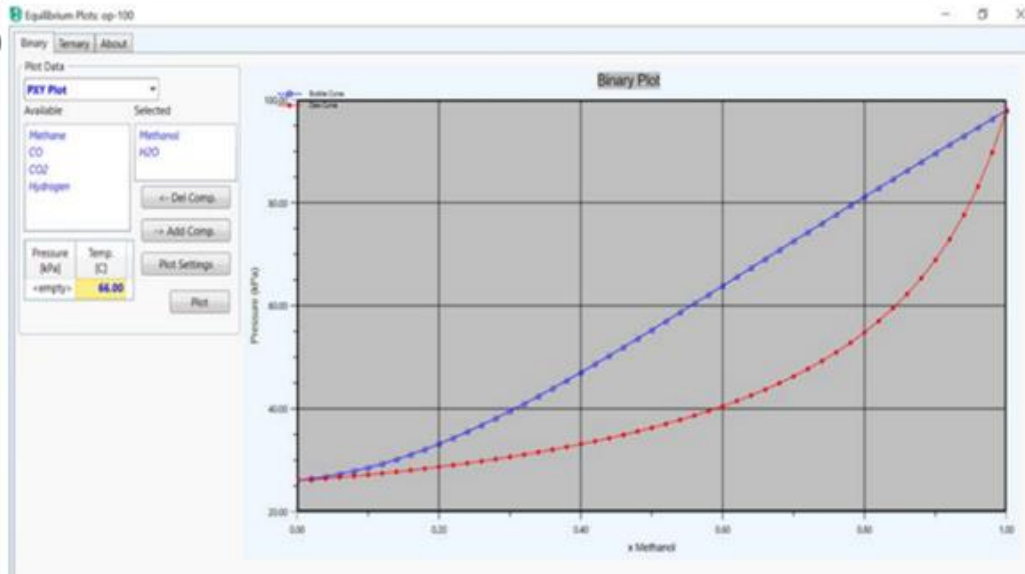
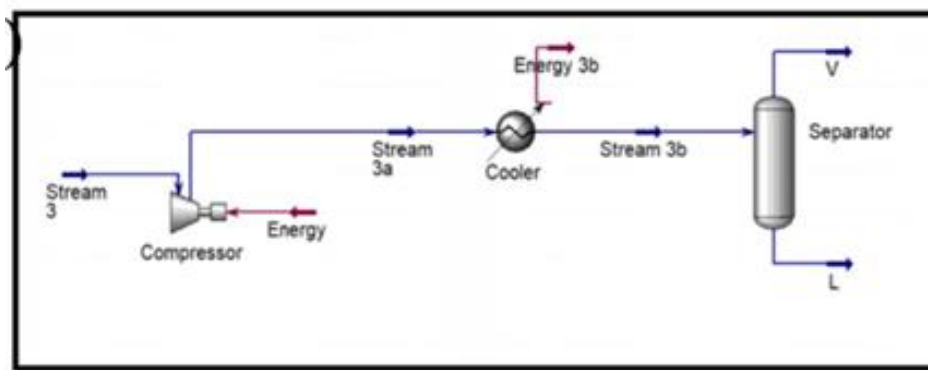


Figure 2. Example of the process flow diagram of methanol production.



(a)

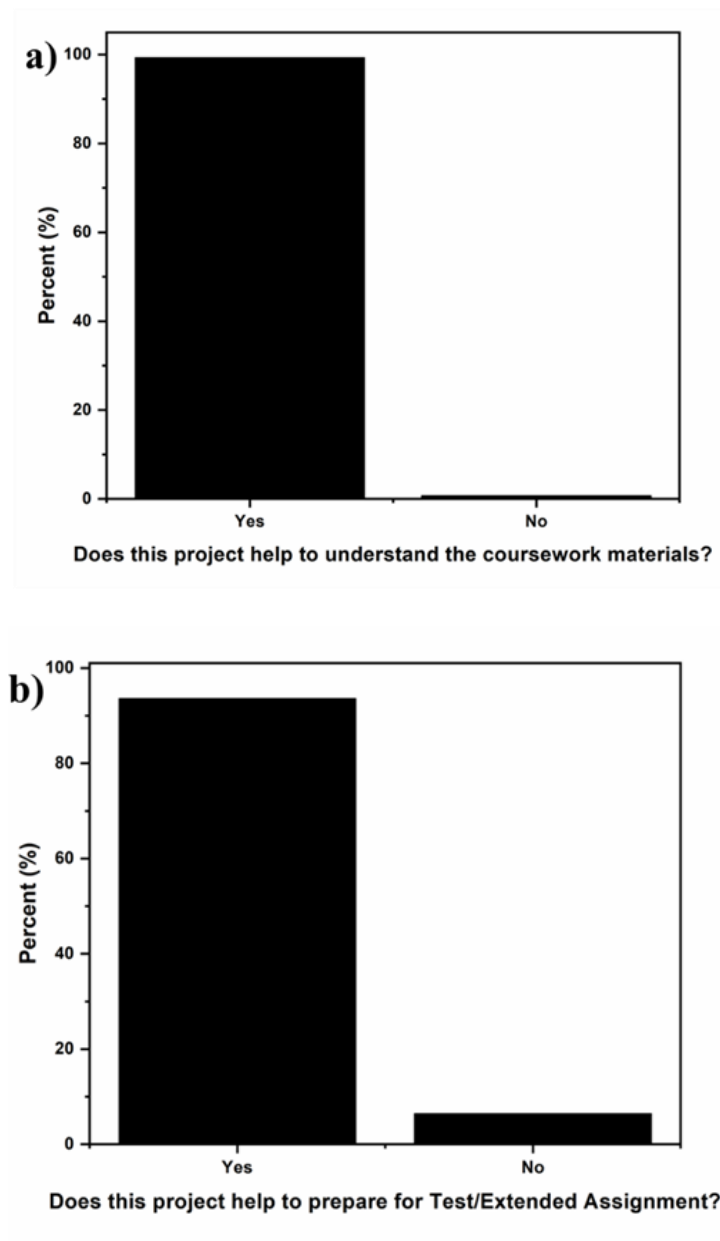


Simulation of the streams

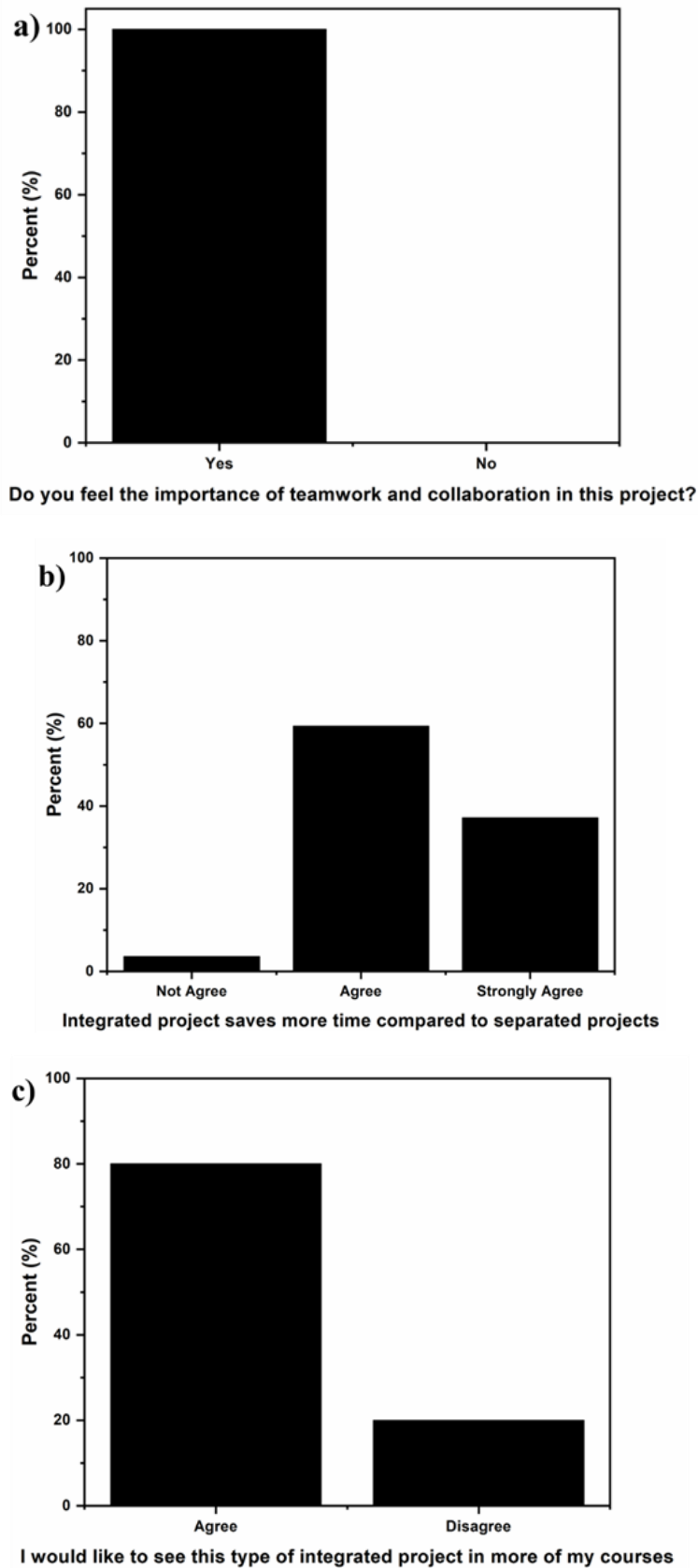
Stream Name	Stream 3	Vapour Phase
Vapour / Phase Fraction	1.0000	1.0000
Temperature [C]	800.0	800.0
Pressure [kPa]	1000	1000
Molar Flow [kgmole/h]	1.862e+004	1.862e+004
Mass Flow [kg/h]	1.921e+005	1.921e+005
Std Ideal Liq Vol Flow [m3/h]	568.1	568.1
Molar Enthalpy [kJ/kgmole]	-3.954e+004	-3.954e+004
Molar Entropy [kJ/kgmole-C]	169.6	169.6
Heat Flow [kJ/h]	-7.361e+008	-7.361e+008
Liq Vol Flow @Std Cond [m3/h]	4.398e+005	4.398e+005
Fluid Package	Basis-1	
Utility Type		

(b)

Figure 3. Examples of HYSYS simulation for a) vapor/liquid equilibrium graph, and b) flash calculation.

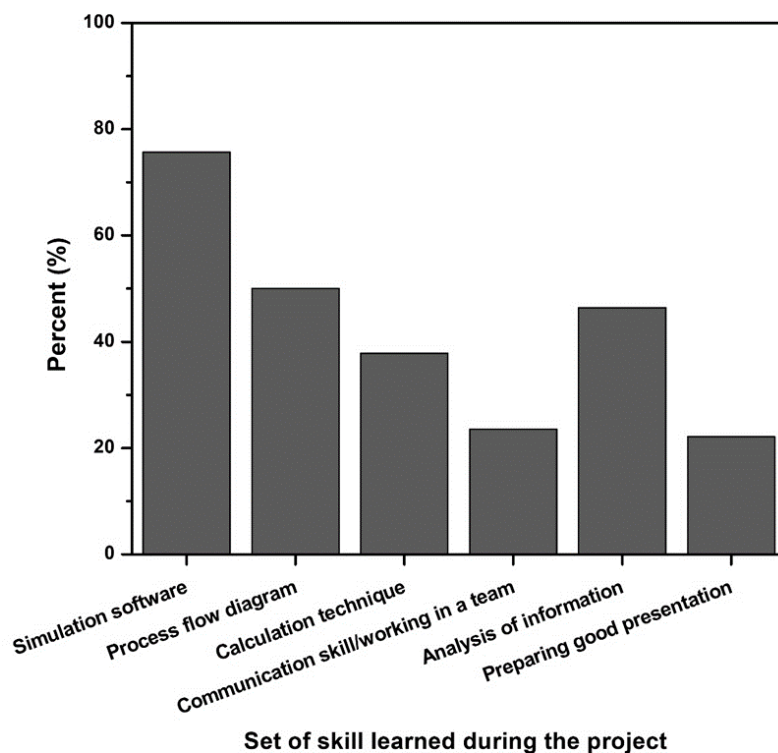


**Figure 4.** Feedback of students on whether the project helps to a) understand the coursework materials, and b) prepare for test/extended assignment.



**Figure 5.** Feedback of students on a) the importance of teamwork and collaboration, b) the project helps to save time, and c) in favor to get the same type of project in other courses.





**Figure 6.** Polling on skills learned during the project.

#### 4. CONCLUSION

The integrated project is intended to give experience to students in implementing concepts that they have learned in class upon the real case problems. By using the knowledge that they have and sharing ideas among the team members, they need to come up with the design process shown in the report and present it in a short video. The project can train students to operate important simulation tools for chemical processes and early exposure to drawing a process flow diagram. The acceptance of this type of project has been very positive by the majority of students, and the skills that they learn include simulation software operation, drawing of process flow diagram, calculation technique, communication skills during working in a team, analysis of information, and preparing a good presentation.

#### 5. ACKNOWLEDGMENTS

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#### 6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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