

***Design of Project-Based Learning to Support Bioprocess Understanding in
Kombucha Project: Integrating Design, Plan, Analysis and Present***

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Abstract

Since the continuous development of Technology in the context of manufacturing, and education sector, the collaboration between manufacturing and education has rapidly adjusted school curriculum to create the new learning approaches. In this research, Kombucha fermentation process was utilized to design learning bioprocess comprehension for the 41 Bioengineering students (Grade 11th students) who will become a machine operator. In addition, this approach also promoted the soft skills such as, Design, Planning, Analysis, and Presentation through Project-Based Learning, which was achieved from the process of Kombucha fermentation, and assessing the learning outcomes by making the edible Kombucha through the application of scientific tool and equipment for measure parameter. According to the learning achievement, and the self-assessment of the soft skills, found that the majority of learners could develop the soft skills and increase the bioprocess comprehension after doing the PBKI experiment significantly. The statistic significant findings ($p < 0.05$). In addition, most of learners could make the edible Kombucha according with bioprocess principle. It can be concluded that the Project-Based learning design through Kombucha fermentation can effectively promote the soft skills among learners and significantly enhance their comprehension of bioprocess.

Keywords: Bioprocess, Kombucha, Project-Based Learning

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Introduction

Nowadays, there are many household products are produced from microorganisms, which has different production methods. But one process that all these products have in common is bioprocess. (Rationalized) Bioprocess's not considered as a new manufacturing process, its evolution has originated for many centuries along with human civilization. Its advantage aims to preserve food and beverages and develop to creating new products from microorganism. For instance, Wine, Beer, and others type of fermented product.

Bioprocess has generally an important role in various aspect. In particular, the industry, it can convert industrial waste and by-products into value-added products in the industry; this biocatalysis-based technology has gained increased attention recently. Comparing with the traditional chemical synthesis processes, bioprocess shows many advantages: mild reaction conditions, environmental friendliness, and a broad range of substrates (Zhang et al., 2019). Nevertheless, there are some disadvantages in the processes, such as instability and lower expression of enzymes, poor performance under certain reaction conditions, high cost due to the complex downstream processing, and limited knowledge in microbiology and the designing of bioprocesses. Therefore, biotechnologies are in demand for novel bioprocesses to develop efficient, sustainable, and economical bioprocesses.

This process consists of feedstock pretreatment, fermentation or biocatalysis, and downstream processing or separation for product recovery and purification. The actual bioprocess are largely dependent on the substrate and organisms used and the nature and applications of the final product. This section will briefly discuss organism choice, fermentation bioreactor design, and separation methods.

Bioprocess mostly associated with fermentation inevitably. Kombucha's considered as a fermented, lightly effervescent, sweetened black tea drink. It is called kombucha tea to distinguish it from the culture of bacteria and yeast. Nowadays, it can be prepared at home or commercially. It was made by dissolving sugar in non-chlorinated boiling water. Tea leaves are then steeped in the hot sugar water and discarded. The sweetened tea is cooled, and the SCOBY culture is added.

In this current, Project-based learning were gradually applied in those laboratory process, It defined as a teaching method in which students learn by actively engaging in real-world and personally meaningful projects. It involved students designing, developing, and constructing hands-on solutions to a problem. The educational value of PBL is to build students' creative capacity to work through difficult or ill-structured problems, commonly in small teams.

According to the development of bioprocess, and Kombucha production, which is rapidly popularized in the current, Project-based learning were used to design learning pedagogy through Kombucha Project. Using Bioprocess as a core theory fermenting those production. In order to consort with 5 skills, involve as follow: Design, Plan, Analysis and Present.

Related Studies

Bioprocess

Bioprocess is considered as a specific process that uses complete living cells or their components (e.g., bacteria, enzymes, chloroplasts) to obtain desired products (Shirinzade,

2022). Transport of energy and mass is fundamental to many biological and environmental processes. Basically, bioprocess was divided into 3 processes. First, cell bioprocessing, the bioprocess engineer that reproduce and robust manufacturing process to produce therapeutic cells. Second, upstream bioprocess, the entire process from early cell isolation and cultivation to cell banking and culture expansion of the cells until final harvest. Third, downstream bioprocess, the part where the cell mass from the upstream are processed to meet purity and quality requirements. According to the definition of bioprocess in each process, it defined as the creation of useful products using a living thing. It's an essential process producing various bio-production (Rendón-Castrillón et al., 2023).

Nowadays, Bioprocess is widespread over every unit of production. It's versatile process that uses living organisms, such as bacteria, yeast, and fungi, to produce a wide range of products. Kortam (2018) divided the benefit of bioprocess into main three criteria as follows (Kortam et al., 2018), Firstly, Sustainability, one of the primary benefits of bioprocessing is that it is environmentally friendly. Bioprocessing uses natural resources to produce products, such as plant material, agricultural waste, and even algae. In addition, it uses the renewable resources. Secondly, Lower Production cost, in this term, microorganism was used in this process means that large quantities of products can be produced in a short period of time. It can reduce the production cost. Lastly, increased economic growth, Markula and Aksela (2022) opined that bioprocessing can create new markets and opportunities for small and medium-sized enterprises (SMEs) (Markula & Aksela, 2022). In addition, it can help to create new jobs in industries that are focused on bioprocessing.

Bioprocesses considered as a manufacturing process which appear for many centuries through the world history. It initially developed from winemaking in Mesopotamia. Brewing was one of the applications of bioprocess engineering. However, it was not until the nineteenth century that the scientific basis of fermentation was established. Louis Pasteur, who discovered the microbial nature of beer brewing and wine making. In the 21st century, progress in bioprocess engineering has followed the development of genetic engineering, which raises the possibility of making new products from genetically modified microorganisms and plants grown in bioreactors. It required contributions from a wide range of disciplines, including microbiology, genetics, biochemistry, chemistry, engineering, mathematics, and computer science.

Project-Based Learning

Project-based learning can be called as PBL. It involves students designing, developing, and constructing hands-on solutions to a problem. The educational value of PBL is aims to build students' creative capacity to work through difficult or ill-structured problems, commonly in small teams (Zhou, 2023). In addition, it defined as a teaching method in which students learn by actively engaging in real-world and personally meaningful projects (Thi-Kim Le Ho Chi, 2018). According to PBL definition, PBL's considered as an important learning approach supporting Science Project inevitably. Sivaloganathan (2015) founded that there are 4 procedures in Science Project, especially in laboratory: experimental design, conducting and collecting data, analysis, and interpretation from the result.

Project-based learning is basically defined as various definition. In particular, Science Project experiment, Kotsis (2024) opined that Experiments are essential to inquiry-based science education because they give students practical experiences that enhance their comprehension of scientific concepts. In addition, Leite and Dourado (2013) also opined that Science project

is conceptualized as solving problem through experiment (Leite & Dourado, 2013). According to the significance, Project-based learning could improve student's active thinking, hand-on, and teamwork ability.

Project-based learning initially developed from Project learning in 2000s. It was a model that organizes learning around projects. It developed from the traditional learning approach. The PBL teaching model emphasizes the need for teachers to immerse students in practical situations and learn. Students who have more practical goals for their learning will also have more substantial guidance than passive as traditional teaching to absorb knowledge. Putri et al. (2021) opined that traditional teaching method mainly prioritized to teacher, but PBL could create atmosphere of learning so that students can actively develop their potential (Putri et al., 2021). Similar to Sumarmi et al. (2021), PBL mode can improve the traditional teaching problems (Sumarmi et al., 2021). Project-based learning promotes students' active learning by strengthening the learning of educational skills in an interdisciplinary and multidisciplinary way.

Project based learning's considered as an essential pedagogy encouraging learner's interest—in particular, collaborative method. Yachulawetkunakorn and colleagues (2017) applied hand-on activity and science fair as one of the steps of Project-based learning (Yachulawetkunakorn et al., 2017). In addition to the context of collaborative method, learners could create artefacts, technological tools, problem-centreness, and certain scientific practices through PBL. Currently, educators promoted PBL in Primary school students consorting with Xiong (2021), she opined that learner had a positive attitude toward PBL in Grade 7th student. In particular, motivation and attitude.

Description of Project-Based Learning to Support Bioprocess Understanding and Integrating Design, Planning, Analysis and Present Skills in Kombucha Project

Background and Overall Structure

Kombucha project is a one of project that belong to Science Project course for students in the second year (Grade 11th) of Bioengineering program at KOSEN program, King Mongkut's University of Technology Thonburi. According to the course description, this project is designed under concept of Project-based learning to encourage students in the Bioengineering program to comprehend about the important process, which is called bioprocess. Bioprocess is an important process in controlling, designing, and developing production from microorganisms. Therefore, learning through Project-based learning (Kombucha project) can encourage students to understand bioprocess easier, because the learners were required to do the experiment by themselves. Moreover, learning through Project-based learning also promotes student to practice of design, plan, analysis, and presentation skills.

The learning process in Kombucha project is divided into 5 parts. Part 1 initially start with a lecture class for students to understand the definition of bioprocess and the relation between bioprocess and kombucha fermentation process. After that, student divided groups in order to brainstorm to design the topics and bioprocess for kombucha fermentation project. Part 2 initially start from students present their designed project topics and bioprocess to the teacher. Then, the teacher gave some suggestions for improvement focus on bioprocess. Part 3 After the teacher approved the project topic and bioprocess, student would write the project proposal to determine the scope of project and work planning. Part 4 start from fermenting kombucha follow design in proposal and collect the sample to determine some parameter

with various tools such as pH meter, reflectometer, microplate reader. After that, the results were analyzed with a statistical program. Finally, Part 4, students presented their results focus on the relation between bioprocess and kombucha fermentation process to peer and teacher. The teacher evaluated and scored them. In case of the student self-assessment aimed to assess the comparative bioprocess's understanding after completed the project. Which is presented in Figure 1.

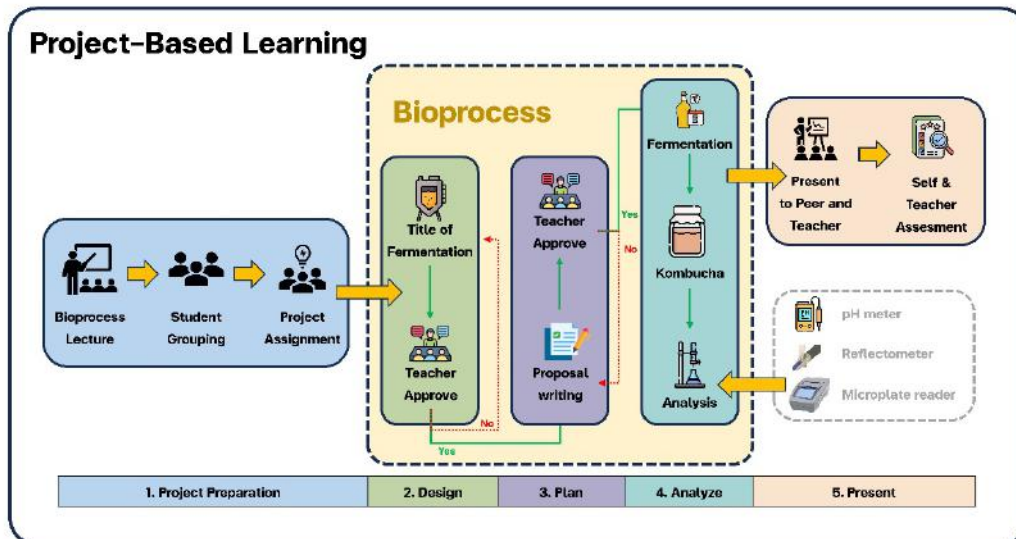


Figure 1: The Overall Structure of Project-Based Learning to Support Bioprocess' Understanding in Kombucha Project

Design of Learning Activities Process

The learning design process in this study is based on the concept of Project-based learning. The Kombucha Project was used as a model for encourage students to understand the mechanisms of bioprocess through integrating design, plan, analysis, and presentation skills of student. In each process of learning, various technologies were used as a tool. Learning process in the Kombucha project is divided into 5 processes within 1 semester (approximately 18 weeks). The details of each process were described in the Table 1.

Table 1: The Correlation Between Learning Process in Kombucha Project and Bioprocess

Activity	Process
Part 1: Project preparation (week 1-2)	In this part started from the teacher explained the definition of bioprocess to student in the classroom and give some assignment such as, search the information on internet about bioprocess in some product from microorganism. After that, the teacher would create a small workshop that involve with bioprocess for student. So, in this part student would know the definition of bioprocess and bioprocess's understanding in kombucha fermentation and the production of products from microorganisms.
Part 2: Design (week 3-5)	In this part started from the teacher showed some parameter that effect to bioprocess in kombucha production. Such as, type of substrate, the amount of microorganism, etc. After that, the student tried to design their experiment for the kombucha fermentation (focus on the parameter that can affect to bioprocess of fermentation). So, in this part student could understand about the parameters that could affect to bioprocess during the kombucha fermentation as well as practiced the design problem skill too.
Part 3: Plan (week 6-9)	In this part started after the project title was approved by the teacher. Then, the student would plan their experiment by writing the proposal. After that, the student presented their proposal to peer and teacher in order to show a method in the experiment. So, in this part the student could understand how to control the parameters during kombucha fermentation as well as practiced the planning and presentation skill too.
Part 4: Analyze (week 10-16)	In this part started from the proposal presentation was completed, student began the experiment as planned in the proposal. During the experiment, various parameters were controlled according to the bioprocess mechanisms. Various parameters were measured with different instruments. The results of the experiment would be analyzed with a statistical program. So, in this part student would have an experience in bioprocess control for determine the quality of kombucha fermentation as well as practiced the analysis skill too.
Part 5: Present (week 17-18)	In this part started after the analysis of an experimental results were completed. Then, presented the results to peer and teachers with oral presentation to discuss the experimental results. In addition, in this part the teacher evaluated the student from a presentation and report. Meanwhile, students would assess themselves in term of the comparative the bioprocess's understanding, and skill before and after completed this project. So, in this part some student could explain about the mechanism of bioprocess that occur during their experiment and more understand about bioprocess. In this part started from the proposal presentation was completed, student would begin experimenting as planned in the proposal. During the experiment, various parameters were controlled according to the bioprocess mechanisms. Various parameters were measured with different instruments. The results of the experiment would be analyzed with a statistical program. So, in this part student would have an experience in bioprocess control for determine the quality of kombucha fermentation as well as practiced the presentation skill too.

Research Design

Participants

The participants in this study were 41 second year students (Grade 11th) of Bioengineering program in KOSEN program, King Mongkut's University of Technology Thonburi. All participants enrolled in a science project course.

Procedure

The kombucha projects were consisted of 5 part which were presented in Figures 2–3.

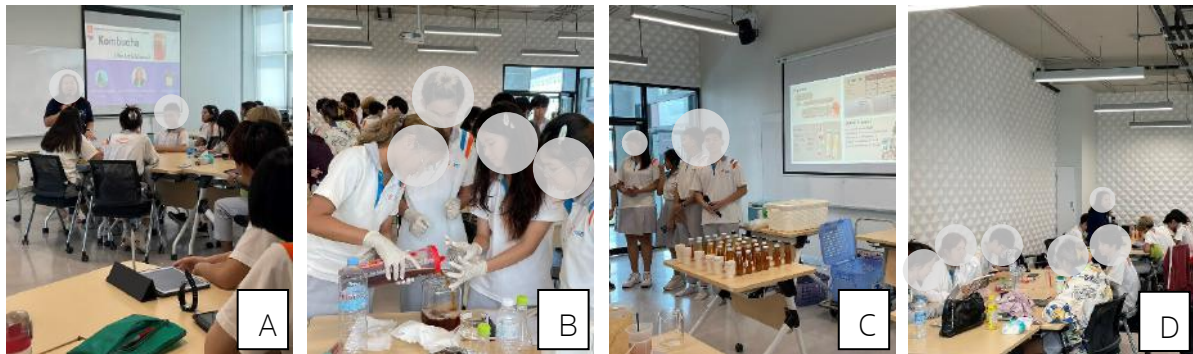


Figure 2: The Procedure of the Kombucha Project in Parts 1–3

Figure 2 showed the process of kombucha project in part 1-3. First, the student learned about the definition of bioprocess and history of kombucha in classroom (A). Then, students participated in workshop activities that involve with the bioprocess in kombucha fermentation (B). After that, students gathered groups and design their experiments for kombucha fermentation present to peer and teacher (C). After the presentation was finished, the student planned the experiment as they designed (D).

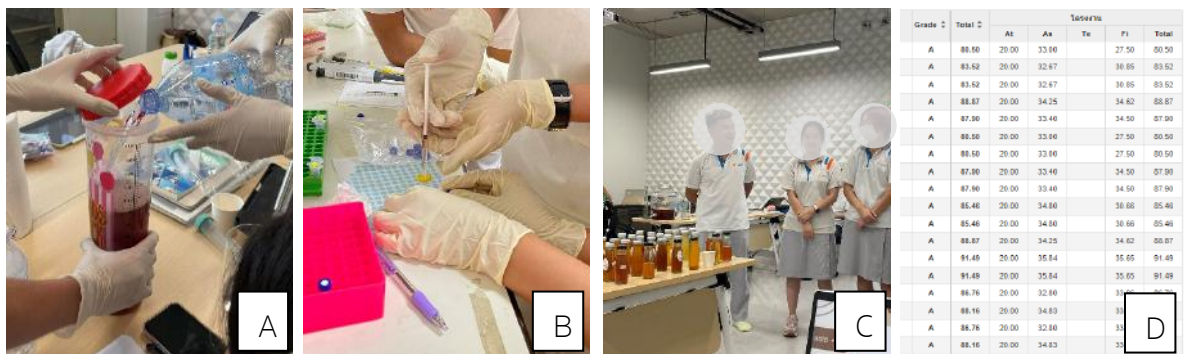


Figure 3: The Procedure of the Kombucha Project in Parts 4–5

Figure 3 showed the process of kombucha project in part 4–5. Initially started with students conducted experiments as they planned (A). Then, students collected the results and analyze with statistical program (B). After that, presented the results to peer and teacher (C). Finally, the students were assessed by teachers on presentation and report. At the same time they assessed their understanding of bioprocess from this project (D).

Data Collection & Data Analysis

The data collection in this study was divided into 2 forms: First is the evaluation from teacher in terms of bioprocess's understanding in kombucha fermentation, which's assessed from the presentation and experimental report's writing. Second is students' self-assessment of bioprocess's understanding, design, plan, analysis, and presentation skills that has changed before and after completing the project. Using self-ratings on a scale of 1–5 in each questionnaire. The result of self-assessment was analyzed with SPSS program by using paired t-test.

Result

Learning Achievement

Based on the teacher assessment by using a rubric on the accuracy of their description of the bioprocess. It was found that all the student' assessments were at grade A (average score is 86.72 ± 3.31), mean that they were able to correctly describe the bioprocess that takes place during kombucha fermentation.

Student Self-Assessment Score

From the results of the student self-assessment, it was found that most students performed at the higher score of learning achievement after do the kombucha project, as shown in table 2 and figure 4. It means that students can develop their understanding in bioprocess as well as design, planning, analysis, and presentation skills after do the kombucha project.

Table 2: Students' Self-Assessment Score Before and After the Kombucha Project

Skills	Experiment	n	Mean±SD	t	P
Understand bioprocess	Before	41	2.13±0.11	13.25	<0.001
	After		3.94±0.07		
Design skill	Before	41	2.19±0.11	12.54	<0.001
	After		3.90±0.09		
Planning skill	Before	41	2.30±0.11	11.53	<0.001
	After		3.93±0.09		
Analysis skill	Before	41	2.27±0.11	10.97	<0.001
	After		3.89±0.08		
Presentation skill	Before	41	2.33±0.11	11.29	<0.001
	After		3.94±0.08		

* $P < 0.05$

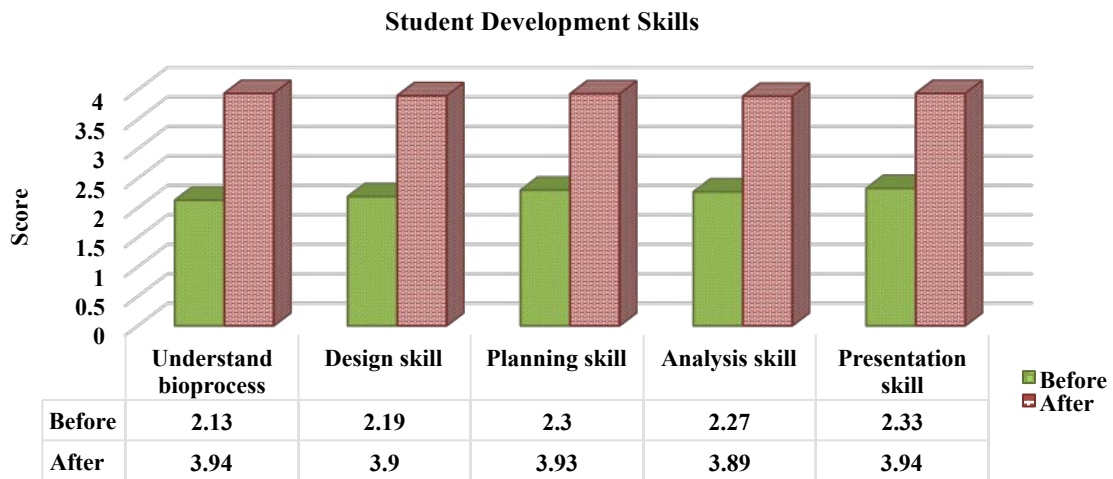


Figure 4: Students' Self-Assessment Score Before and After the Kombucha Project

The Kombucha Project Development of Student Skills

From the result showed that the most developing skill after do the kombucha project was planning skills is 33.75%, analysis skill is 32.50%, design skill is 20.00% as well as presentation skills is 13.75% (Figure 5).

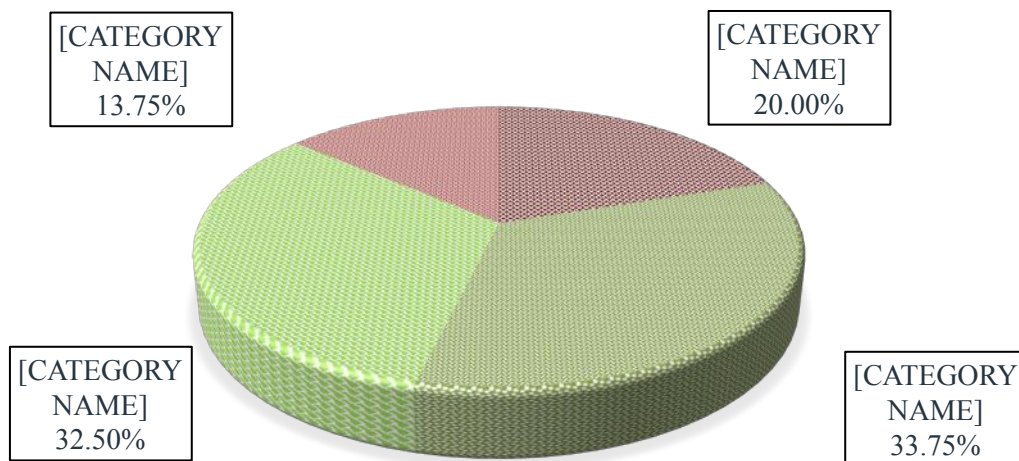


Figure 5: The Student Skill Developed After the Kombucha Project

Discussion and Conclusion

This study investigated the development of understanding bioprocess of bioengineering student through do kombucha project. In addition, planning skill, analysis skill, design skill and presentation skill has also been developed. Because, during learning process the student gain experience in controlling bioprocess from various parameters to kombucha fermentation that students design by themselves. So, students will encounter problems and must find solutions from real situations on their own.

From the results can conclude that learning with Project-based learning able to support the ability to understand bioprocess during product production. Moreover, planning skill, analysis skill, design skill and presentation skill has also been developed. Therefore, if

teachers want students to understand bioprocess in product production more. Students should learn through do some project rather than lecture in classroom only.

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