A Course Integrating Project-Based Learning (PBL) and Industry-Academia Collaboration

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Abstract

In fermentation technology courses, a majority of students with non-engineering backgrounds found the fermentation theory content challenging and uninteresting. The primary practical focus of the project involves beer brewing, coupled with collaboration with industry partners such as Winners and breweries in an industry-university cooperation model. This collaboration includes providing access to industry production equipment and addressing industry-oriented problems. Through industry or industry-academia cooperation, students in the classroom are organized into sub-groups, supplemented by a Problem-Based Learning (PBL) approach and a learning-by-doing experimental course. A 9-item questionnaire was administered using a 5-point scale, with a total of 32 students participating. The results showed that students affirmed that the course enhances their proficiency in biotechnology, the inclusion of guest lectures boosts their enthusiasm for learning, and they perceive theoretical knowledge as crucial for their future careers. Moreover, inviting industry experts to share experiences and providing hands-on experience with related products are beneficial for promoting students' desire to learn. Additionally, the students' perception after taking the practical course was significantly higher than before they took the practical course regarding enhancing professional competence and learning motivation. Furthermore, female students demonstrated significantly higher performance compared to males. Finally, the researchers provide some implications for future teaching and studies based on the results.

Keywords: Fermentation, Project-Based Learning (PBL), Industry-Academia Collaboration

1. Background/ Objectives and Goals

(1) Motivation for Teaching Practice Research Project

The factors leading to inadequate student learning outcomes are numerous. In the past, students majoring in biology-related disciplines have taken courses in fermentation technology. Although biotechnology plays an increasingly prominent role in addressing resource crises and improving medical, health, and environmental conditions, fermentation technology is a crucial component of biotechnology. The content of fermentation technology ranges from descriptions of microbial strains and culture media preparation considerations to introductions to the basic principles of fermentation equipment, analysis of factors affecting fermentation processes, and methods for strain improvement. In addition to microbial strains, there are also topics such as culture devices, antibiotics, and recombinant cell growth factors. For students without an engineering background, content that is theory-driven may be overly challenging for those lacking strong motivation.

When introducing the PBL (Problem-Based Learning) approach, the abovementioned traditional theoretical lectures, which may be too challenging, can make students feel "uninteresting," naturally leading to a lack of willingness and motivation to explore. The key lies in how to spark motivation through interesting topics. Furthermore, teachers may find that topics they consider important are not of interest to students, while topics that interest students may be perceived by teachers as too superficial, lacking further discussion and learning value. Therefore, satisfying this condition is not always easy. Typically, students find topics interesting when they relate to their own life experiences and familiar issues. Because of their life experiences, students are more likely to have their own perspectives and ideas, which allows for discussions to be more continuous and not abruptly discontinued. Hence, educators should consider the following: **What issues require the group's attention and what facets of solutions are necessary, the practical value produced, and the type of professional expertise required.**

In conducting “learning by doing” laboratory experiments, the most common approach is often through cookbook-style activities, where students simply follow instructions. Although this adheres to standard operating procedures (SOP), it often leads to decreased student engagement and renders the process meaningless. Introducing industry experts into campus implementation is essential for many practical courses. However, industry experts mostly engage in activities such as delivering topic-specific lectures, guiding projects, or co-teaching in practical courses. This is often because industry experts lack pedagogical expertise and interaction skills with students, often relying on personal experiences or corporate management styles. Although they collaborate with teaching faculty to plan courses, their teaching role becomes challenging without understanding the current campus ecosystem or the learning characteristics of the class. So, teachers should consider: **Is there a necessity for industry professionals to instruct specific courses, and if so, which ones? What disparities exist between instruction by industry professionals and campus-based**

instructors?

On the other hand, planning corporate visits is a common method in practical courses to understand industry practices and interactions. This instructional activity involves considerations such as whether the industry is willing to open for visits, whether the timing aligns with students' class schedules, whether it meets the requirements of student courses, whether the company demonstrates innovative development trends, and whether it can promote students' reflection and verification of classroom learning. If it fails to fulfill the aforementioned functions, it often ends up as a one-time corporate sightseeing activity. So, teachers should contemplate: **What aspects should be considered during a corporate visit related to your project, and what information should be comprehended? What characteristics of products should be comprehended during corporate visits?**

Taking a step further, industry-academia collaboration aims to bridge the gap between theory and practice by incorporating "practical learning issues" into industry visits. By bringing back "industry-real problems for discussion" from the perspective of corporate demands to the classroom, exchanging experiences between classroom instructors and industry professionals, and fostering discussions or hands-on learning to address real industry scenarios, this project aims to achieve its goals in the future.

(2) The theme and research objectives of the teaching practice research project

The research theme and objectives of applying for the "Technical Practice Teaching Practice Research Project" can be achieved through collaborative efforts with industry experts or by integrating industry-academia collaboration into curriculum planning, fostering a hands-on learning approach. This aims to cultivate students' ability to translate theoretical knowledge into practical skills, enhance their professional skills in practical applications, or increase their readiness for employment, thereby reducing the gap between theory and practice.

2. Methods

(1) The research subjects

The course is an elective course for the Biotechnology Department, targeting students from the first to fourth year of the Biotechnology Department. Students are required to have taken basic subjects such as biology, general chemistry, and organic chemistry.

(2) Research methods and tools

This project adopts Problem-Based Learning (PBL) and experiential learning through hands-on experience. Regarding group work, students engage in industry-driven new product development. Students autonomously learn within their groups, presenting the learning outcomes of their knowledge base and showcasing the results of their product development. They also explain the characteristics of their achievements, including (A) Presentation of Knowledge Base: relevant theories, mechanisms, and examples of industry-related product applications. (B) Presentation of Product Results: market demand analysis, product functionality, etc.

(3) Scale Analysis

There were a total of 32 participants, with 14 males and 18 females. The original questionnaire consisted of 24 items. A pilot study was conducted using SPSS 17.0, and 15 items were removed after factor analysis due to their unsuitability. The resulting questionnaire contained two factor groups: Factor One (summarized as "Enhancing Professional Competence") comprising 6 items, and Factor Two (summarized as "Enhancing Learning Motivation") comprising 3 items. The internal consistency of the questionnaire, measured by Cronbach's Alpha, was found to be 0.883, indicating good reliability. The questionnaire was able to explain 65.21% of the variance, demonstrating good validity (see Appendix).

(4) Research design

After the group identifies the problem, the following discussions are conducted in a PBL manner:

(a)What problems does the group need to address/what aspects of answers are needed → Understanding the problem, analyzing the problem, defining the scope

(b)Establishing hypotheses → Understanding the various mechanisms needed to solve the problem

(c)What kind of professional knowledge is needed → Group discussion to address the details required to solve the problem

(d)Sources of professional knowledge → Classroom instructors, the internet, professional books, professional journals

(e)Generated practical value, good products → What constitutes "good," how to achieve it

In practical courses, the following discussions are conducted:

(a)How to do → Teaching basic skills.

(b)Do we need industry professionals to teach certain courses/which courses → Introducing industry experts based on the needs of student groups.

(c)What are the differences between industry professionals teaching and campus-based instructors teaching → Teaching practical skills based on the needs of student groups.

(d)How to do it well → Continuous improvement, with professional advice provided by industry experts and instructors.

(e)Presentation of product outcomes → Announce the holding of a competition judging session, providing competition prizes.

(f)Construction of knowledge → Proposed by group discussions, starting from problem formulation, hypothesis generation, experiment design, verification, and conclusion drawing.

(5) Implementation process

(A) Introduction and Sharing: Introduce the concept of Project-Based Learning (PBL) and share past experiences and outcomes of PBL operation.

(B) Group Formation: In the 1-2 weeks before the course, teachers provide an explanation of PBL to foster a spirit of teamwork. Students are divided into several cooperative learning groups of 5-6 people, and the responsibilities of the teacher and group members are clarified. This allows team members to have opportunities for mutual learning, understand how to communicate with others, and learn new perspectives from each other.

(C) Problem: The teacher presents a question with a relatively vague definition that students find interesting. Various reference question types are provided to give students a basis for consideration. When facing real problems, each group member needs to spend an additional 6-7 hours collecting and studying background information related to the problem in advance. They then cross-reference the information to understand the basic concepts of the problem.

(D) Analysis of Assumptions: After each group member has a preliminary understanding of the problem, they engage in group brainstorming, discussing and exchanging their views to analyze the assumptions implicit in the problem and gradually unravel its mysteries. They then prioritize the project goals and expected outcomes based on their importance.

(E) Establishing Issues and Division of Labor: After brainstorming as a team, gradually formulate the knowledge required to solve the problem. Evaluate the topics and scope that each group member still needs to learn, then engage in further learning and discussions to find solutions to the problem, which will serve as the basis for future actions. Once each student has selected their respective tasks, they begin gathering information through various learning resources such as the internet, CDs, textbooks, papers, teachers, and academic experts for self-guided research. The requirements are provided to the instructor as teaching guidelines.

(F) Classroom Theoretical/Technical Instruction: After discussion among student groups, the required professional knowledge is identified. Following appropriate communication with teachers and industry experts, suitable theoretical and technical courses are arranged to address student questions.

(6) Practical course

(A) Implementation Action (Learning by Doing): Within the existing group structure, team members transform the improvement proposals discussed into concrete practical investigations. They sequentially complete various action tasks and observe whether the original problems gradually dissolve as a result of these actions.

(B) Evaluation and Analysis: Using the evaluation questionnaire (Appendix), students respond using a 5-point scale, and data analysis was conducted afterward. The results of brewing produced by each group were evaluated and discussed.

(C) Iterative Review/Reflection

To cultivate team members' higher-order critical thinking abilities, the group mentor typically guides them from objective and explanatory questions to reflective and decisive questions. They counsel group members to take decisive actions to verify whether actual problems can be effectively resolved, thereby teaching them to reflect and review. After the last round of actions and reflections, if the actual problems still cannot be completely resolved, it is necessary to adjust or reconstruct the problem-solving strategies, modify or propose new action plans, so that the next stage of action can achieve the learning objectives.

(D) Repeat Implementation

The revised experimental conditions and recipe compositions are rehearsed again in a new way, allowing the problems with the previous product to be continuously replaced by new processes and formulas. This can return to the first stage to re-examine and analyze the problem, repeat all the above steps, and make problem analysis and action reflection a cycle of sustainable development.

(E) Presentation of Results

Each group presents their results through oral reports, written reports, slide presentations, audio-visual media displays, etc. Each student needs to provide a clear explanation and communication of the entire execution process, content, discovered results and methods, as well as the conclusions drawn.

(F) Conducting Evaluation

After the groups present their results, external experts are invited to score and provide comments. The evaluation criteria include the quality of the product itself, innovation, operational skills, the group's operating model (analytical process), depth of learning in professional knowledge, and intellectual property output.

(7) Industry-Academia Collaboration

(A) Industry Issue: Through practical courses, introducing industry instructors to teach students industry-specific skills for practical course operations.

(B) Market Demand: By visiting enterprises and interacting with industries, we can understand the current market demand.

(C) Industry-academic collaboration: Establishing product processes, introducing innovative technologies, and exploring different methods to yield various products and outcomes.

(D) Commercialization: Through practical courses, exploring different manufacturing processes in the hope of achieving commercial outcomes.

(8) Practical course design

The theme of this session is brewing beer, and for group experiments, we utilize the Taguchi L9 experimental design to optimize our investigation using three levels for four factors. The factors include the proportion of hops, the ratio of RO water to tap water, the mashing time, and the proportion of malt.

3. Results

In Table 1, under Factor 1 (Enhancing Professional Competence), three items showed higher ratings following the completion of the course. These items include: "This course enhances the ability to apply biotechnology," "Guest lectures are helpful in increasing my interest in this course," and "I believe theoretical knowledge is more helpful for my future employment." In essence, students affirmed that the course enhances their proficiency in biotechnology, the inclusion of guest lectures boosts their enthusiasm for learning, and they perceive theoretical knowledge as crucial for their future careers.

Moreover, under Factor 2 (Enhancing Learning Motivation), two items showed higher ratings following the completion of the course. These items are: “Industry expert practical teaching is helpful in increasing my interest in this course,” and “Experiencing the product is helpful in increasing my interest in this course.” In other words, inviting industry experts to share experiences and providing hands-on experience with related products are beneficial for promoting students’ desire to learn. The results mirrored the findings of Zhao et al. (2020), indicating that the combination of PBL and CBL could serve as an effective approach to enhance students' performance and improve their practical skills.

Table 1: The Assessment Scores of Students in Pre-test and Post-test of the Course (a five-point scale)

Factor	Item	Pre-test	Post-test
Factor 1: Enhancing Professional Competence	1. This course is very important in the application of biotechnology.	4.156	4.152
	2. This course enhances the ability in applying biotechnology.	4.375	4.455
	3. This course is important for future research.	3.969	3.848
	4. Guest lectures are helpful in increasing my interest in this course.	4.281	4.394
	5. Information from websites is helpful in increasing my learning in this course.	4.344	4.303
	6. I believe theoretical knowledge is more helpful for my future employment.	3.719	3.848
Factor 2: Enhancing Learning Motivation	7. Industry expert practical teaching is helpful in increasing my interest in this course.	4.438	4.455
	8. Visiting external companies is helpful in increasing my interest in this course.	4.531	4.424
	9. Experiencing the product is helpful in increasing my interest in this course.	4.438	4.515

From Table 2, the results indicated that the students after they took the practical course (*M* = [24.969], *SD* = [2.443]) was significantly higher than before they took the practical course (M = [24.844], SD = [2.952]), t([31]) = [.371], p = [< .05] on enhancing professional competence, and the results also indicated that the students after they took the practical course (M = [13.438], SD = [1.366]) was significantly higher than before they took the practical course (M = [13.406], SD = [1.411]), t([31]) = [.658], p = [< .001] on enhancing learning motivation. Through paired samples T-tests analysis, participants showed significant improvements in both factors of "Enhancing Professional Competence" and "Enhancing Learning Motivation" in pre- and post-tests, with correlation coefficients of .371 and .658 respectively. The findings echoed Rudhumbu's research (2022), suggesting that peers who are highly active and motivated can inspire similar behavior in students within the classroom. Additionally, certain learning materials and artifacts in textbooks and other educational resources may perpetuate stereotypes, potentially impacting the confidence and motivation of female students to engage actively in learning.

Table 2: The Summary of Paired Samples Correlations on Factor 1 and Factor 2 on Pretest and Post-test (N=32)

T-Test	*M*	*SD*	*t*	*Sig.(2-tailed)*
Pre-F1	24.844	2.952		
Post-F1	24.969	2.443		
Pre-F1 & Post-F1			.371*	.037
Pre-F2	13.406	1.411		
Post-F2	13.438	1.366		
Pre-F1 & Post-F2			.658***	.000

From Table 3, a Pearson product-moment correlation was conducted to assess the relationship between gender and academic performance. There was a significant positive correlation between the two variables, $r(31) = .506$, $p < .01$, with high levels of gender associated with higher academic performance. Female participants demonstrated significantly higher performance compared to males, scoring 90.78 and 84.50 respectively, with an F-value of .506**, and standard deviations of 6.454 and 4.596 respectively. The findings aligned with Matovu's research (2020), demonstrating distinctions in students' academic self-efficacy and academic performance based on gender. Conversely, they diverged from Hu & Cheung's findings (2021), which revealed no significant gender-based disparities in academic performance.

Table 3: The Summary of Correlations on Gender and Academic Performance (N=32)

Gender	*N*	*M*	*SD*	*F*	*Sig.(2-tailed)*

Male	14	84.500	6.454		
Female	18	90.778	4.596	.506**	.002

(2) Teacher's Teaching Reflection:

In this study, the researchers found that students enjoy courses that involve practical instruction; industry-based practical teaching, product experiences, off-campus company visits, and group product projects are helpful in stimulating student interest in learning; academic and theoretical lectures are not well-received by students; students show limited willingness to spend time gaining further understanding of products and processes in enterprises, and the most significant improvements observed in the study are group discussions and product design packaging.

(3) Students' Learning Feedback

In this study, students' learning feedback is as follows.

What was your biggest takeaway from this course?	
S1	Through the group presentation at the end of the semester, I gained a deeper understanding of beer brewing knowledge and delved into a field I had never explored before.
S2	I learned about various aspects of beer brewing such as brewing methods, the impact of different malts, the uses of hops, differences in yeast strains, and the principles of fermentation.
S3	Previously, I wasn't much of a drinker, but after taking this course, I started to learn about tasting and began to understand what styles of beer flavors I enjoy and suit me best. This has been my biggest takeaway.
S4	I learned about the brewing process.
S5	I learned about the brewing process itself and realized that there are many details to pay attention to during the process. Lastly, during the preparation of the presentation report, it was crucial to collaborate effectively with my team members. Only through discussions could we stimulate different creative ideas.
S6	Understanding of beer-related knowledge and methods of tasting and collaboration.
S7	Understanding of craft beer.
S8	Enjoyable collaboration in the brewing process.
S9	Understanding of the brewing process and factors to be aware of, as well as the relationship between ingredients and finished product flavors.
S10	Enhancement of understanding of fermentation techniques and practical skills.
S11	The same material, with different dedication and effort, will result in different outcomes. In a team, there can be different opinions, but actions must be unified to demonstrate the greatest power of cooperation.
S12	Familiarity with the beer brewing process.

S13	Acquiring knowledge about alcohol and through reports and practical work, cultivating the ability to organize documents and practical skills.
S14	This course offers various learning methods, including lectures, practical operations, visits, and experiences. Additionally, learning from experiences shared by individuals in different roles, such as bosses, teachers, classmates, senior students, and professors from other schools, enables diverse learning opportunities. The course content, whether through lectures or practical exercises, is closely related to daily life and easily understandable. Within the same timeframe, students gain more experiences and ideas than other courses, making it very meaningful.
S15	Learning the brewing process and consuming alcohol every few weeks.
S16	In addition to learning professional knowledge, practical operations provide us with real experiences, and we gain valuable insights from them. The lectures also offer helpful suggestions from actual breweries, which greatly aid our learning process.
S17	Tasting different types of alcohol has expanded our knowledge of beverages.
S18	We've gained many directions for further exploration. For instance, fermentation, which can be applied in various contexts such as yeast fermentation and cocoa fermentation, offers avenues for deeper research. Understanding the factors influencing fermentation has also sparked our curiosity for more in-depth studies.
S19	These experiences have been quite unique and have given me a different perspective on life sciences. Whether it's understanding the brewing process or the teacher's explanations on fermented products during class, they have left a deep impression on me.
S20	Learning about the brewing steps and precautions, as well as the flavors of alcohol (such as fruity, fatty, and bitter flavors).
S21	Understand the complete brewing process and gain insight into beer.
S22	Methods, sequences, and enjoyment of tasting.
S23	Being able to see the key points emphasized in the brewing of various types of alcohol from a professional perspective, providing a great opportunity to understand the industry.
S24	First-time brewing experience, tasting various types of alcohol, and introductions from industry professionals.
S25	Learning how to brew beer.
S26	Understanding the process and ingredients of brewing alcohol is more profound when done firsthand.
S27	The foundation knowledge and experience of brewing, along with the camaraderie of teamwork with classmates.
S28	I learned how to collaborate as a team, relying heavily on everyone's cooperation for both brewing trials and subsequent reports.

S29	The opportunity to gain hands-on experience from brewing is invaluable.
S30	The importance of teamwork.
S31	Fermentation can be applied not only in brewing beer but also in many agricultural techniques such as pesticides and fertilizers. For someone like me who enjoys drinking beer, the chance to brew it myself brings great joy.
S32	I gained a lot of knowledge about beer brewing, as well as brewing techniques, which was very beneficial.

Recommendations and Reflections

1. Students' self-positioning: The importance of this course in future research and its assistance in future employment are rated low.
2. The use of English website data by groups and practical teaching for future employment assistance received significantly lower scores.
3. Students generally dislike classes focused mainly on theoretical knowledge.

Acknowledgments and Legal Responsibility

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Appendix

Questionnaire

Factor 1: Enhancing Professional Competence					
1. This course is very important in the application of biotechnology.	5	4	3	2	1
2. This course enhances the ability in applying biotechnology.	5	4	3	2	1
3. This course is important for future research.	5	4	3	2	1
4. Guest lectures are helpful in increasing my interest in this course.	5	4	3	2	1
5. Information from websites is helpful in increasing my learning in	5	4	3	2	1

this course.					
6. I believe theoretical knowledge is more helpful for my future employment.	5	4	3	2	1
Factor 2: Enhancing Learning Motivation					
7. Industry expert practical teaching is helpful in increasing my interest in this course.	5	4	3	2	1
8. Visiting external companies is helpful in increasing my interest in this course.	5	4	3	2	1
9. Experiencing the product is helpful in increasing my interest in this course.	5	4	3	2	1

Note: 5-strongly agree; 4-agree; 3-neutral; 2-disagree; 1-strongly disagree