

International Journal of Learning, Teaching and Educational Research
Vol. 21, No. 3, pp. 359-378, March 2022
<https://doi.org/10.26803/ijlter.21.3.19>
Received Jan 18, 2022; Revised Mar 18, 2022; Accepted Mar 28, 2022

The Relevance of Learning Methods in Realising Student-Centred Transformative Learning

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Abstract. This research aims at determining the most appropriate learning method in one cluster of students enrolling in the courses of SPD and EABP. For the data analysis, a survey was performed on the STEM cluster. The sample comprised the students of SPD and EABP, two courses in bioprocess engineering. The sample was determined on the basis of the clustering groups. The next procedures were FGD, interview, and questionnaire distribution. The quantitative data were analyzed with a systematic review. The result showed that the course-learning outcomes were achieved to the maximum percentage with PBL and PrBL. Moreover, the results discussed how students experience learning in SPD and EABP courses, where the activities included collaborative learning in a cluster mode. Learning methods in the bioprocess-engineering study program have been transformed from the traditional model (educator, or supervisor-centred learning) into Student-Centred Learning (SCL). Learning conduct and the characteristics of PBL and PrBL increase students' motivation in self-directed learning; while educators or supervisors as instructors allow students to focus on their own learning; and they are not heavily reliant on their educators to give them instructions. PBL and PrBL in SCL promote students' role as the core of the learning, in which the students themselves investigate and explore the process and design their own learning. This research contributes to STEM-clustering application with student-centred transformative learning in bioprocess engineering.

Keywords: strategies; clustering; learning method; assessment method

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1. Introduction

The clustering method is a process of labelling objects, which is based on minimizing the similarities between classes and maximizing the similarities in those classes, which are widely applied in science (Wu et al., 2016); for example, in Science, Technology, Engineering, and Mathematics (STEM) clusters. STEM-cluster collections and processes-learning data can contribute to process-mapping and learning outcomes. The process is based on knowledge and skill-based, observable experience, which is beneficial for the sustainability of learning and students' carriers. The cluster method contributes to practical learning development, in order to obtain professional high-quality knowledge.

Professional knowledge is the amount of knowledge, skills (soft skills, technical skills, and working qualifications) and other necessary skills in a process of teaching students to have practical skills in high-quality learning (Stanca, Dabija & Păcurar, 2021).

Therefore, conventional education needs to be transformed into experiential learning with entrepreneurship and practical experience, which is known as Project-Based Learning (PBL) and Problem-Based Learning (PrBL). To improve this learning method, an institute, or faculty, or the study programs of a university must collaborate with the partners, in order to develop and strengthen the collaborative framework. The main direction is to re-engineer the learning methods, to become more relevant to real-life situation in the industry, to facilitate collaboration through various learning environments (face-to-face learning, practicum, workshops, seminars, and web-based opportunities) that provide relevant and modern learning.

Previous research claimed that the cluster method effectively solves the problems encountered during the learning process; while some say that the cluster itself is not the end result – but that it is only one way to find out what method is the most suitable in learning (Wu et al., 2016; Xu, King & Wunsch, 2008). Other research has shown that students who are enrolled in the student group have a high preference for learning styles; while students who study individually show lower results (Abdelhadi, 2017; Toledano-O'Farrill, 2017). These previously mentioned research projects suggest that there are discrepancies in the results.

This state provides possibilities for exploring the implementation of the cluster system in learning. In STEM education alone, especially in bioprocess engineering, research on the implementation of cluster learning with student-centred transformative learning is still rare. Therefore, in this study, the authors investigated STEM-clustering application with student-centred transformative learning in bioprocess engineering.

PBL and PJBL can be conceptualized, as thorough and coherent learning activities, which are usually applied by the stakeholders of learning activities (educators, educators' assistants, lab managers, and students) who believe that learning motivation is supported by all learning values and by the characteristics in a certain period. Students' learning motivation is reflected by their learning pattern.

By understanding students' learning model, learning strategies and the main performance predictor, educators or supervisors should be able to provide personalized instructions to their students (Zhang et al., 2021). Learning models can be considered as the data. Determining learning models can be based on content (all behaviours related to the access to learning materials); assessment (all access to learning assessment); assessing grades; behaviours to check all subjects' grades (this behaviour has been identified as the initial indicator); interactions (all behaviours related to individual interactions, including interactions between students or interactions between educators and students).

PBL and PrBL can be optimized thoroughly to consider what the benefits are for educators and students, curriculum development, the relationship with the educators' background skills and all the variables to be applied and to achieve better grouping performance. The main contribution of this research is to propose a new method (Wang et al., 2021) in determining which method is the most appropriate to motivate students to learn more independently in the Student-Centred Learning (SCL) approach in PBL and PrBL.

SCL requires students to be more active. Educators may use various teaching methods that promote students' critical thinking and problem-solving skills. Active learning requires students to apply meaningful learning and to think about what they are doing. PBL focuses on experiential learning, in order to explain and solve any problems. PrBL provides a more challenging approach, thereby motivating, and encouraging fun learning. There can be strong reasons for improving the motivations in learning. Knowledge is resulted from a combination of experiencing and transforming that experience. Therefore, experiential learning is considered as active learning.

This concept is based on the constructivist approach in learning, which believes that students should be actively involved in their learning. Decision-making in collaborative learning promotes critical thinking. Problem-solving based on PBL requires social interactions and cooperation, active and experiential learning, and a critical review of the social issues (Martínez Casanovas, Ruíz-Munzón & Buil-Fabregá, 2021). Viewed from the perspective of the Goal-Setting Theory, PBL and PrBL learning show that motivation itself is a learning process. Every student is able to achieve learning goals (Locke & Latham, 2020). Learning goals encourage motivation, in order to achieve better performance. The set goals and self-related processes are closely related and significant in improving learning performance (Neubert & Dyck, 2016).

According to the Goal-Setting Theory, PBL and PrBL are objective-oriented, thereby providing sustainable infrastructure to reach successful projects with economic, social, environmental, and organisational benefits. Learning outcomes are directed to the learning-performance cycle, which is built on the basis of the effects of determining learning outcomes that are based on the plan-do-check-act ideology (PDCA) (Liu, et al., 2020).

The purpose of this study is to determine which learning method is the most appropriate for students in a STEM clusters, and specifically those observed in SPD and EABP. Moreover, the research will investigate in what way these methods could improve the learning performance of students.

2. The Literature Review

2.1. Project-based learning

The Goal-Setting Theory (GST) demonstrates that how students learn would determine their learning outcomes (Locke, 2016). Many educators nowadays integrate constructivism into learning; since this method sees educators and students as integral parts of the learning process. In line with the Constructivist theory, learning is an active process in which educators and students are involved together, in order to construct meaning in the learning situation. New knowledge can be attained actively, either by educators or students, by connecting the new knowledge with their background knowledge, which is aligned with the faculty curriculum. Project-based learning (PBL) is one of the pedagogic forms that seek to apply the Goal-Setting Theory (GST).

This approach does not only represents other different teaching methods, but it also revamps the traditional-learning method fundamentally (Maran et al., 2021), because PBL emphasizes the process that is characterised by knowledge and goals, not only as the way of attaining certain final products (Barrane et al., 2020). GST shows a greater need to develop study programs, which are based on the PBL approach. This approach is often more favourable in teaching science, technology and mathematics (STEM). GST combines constructive ideas by putting the emphasis on the importance of selecting learning modules and implementing industry-based learning, which is related to the subject, the syllabus, and the curriculum, thereby creating a learning environment that attracts students.

A significant learning method is when educators and students are building meaningful learning together, in order to make a creative, innovative, and structured process that they can share with others. The Course of Synthesis and Process Design (SPD), which is combined with advanced technology, is a long process that requires transformation in the learning and working method. Educators adopt teaching methods, based on knowledge, perceptions, beliefs, and values that influence their teaching methods and responses to educational transformation.

One field where the knowledge of management is necessary is project-based learning. In this study, SPD and the Economic Analysis of the Bioprocess Project (EABP), as can be seen in the curriculum of bioprocess engineering study program, Biotechnology faculty, Del Institute of Technology (IT Del), have been categorized in the STEM cluster, and then analyzed to demonstrate educators as the knowledge managers. PBL suggests that students play active roles, whereby they are able to complete their authentic tasks and learn from designers or instructors in solving problems, while applying their knowledge in SPD and EABP. PBL is well-structured, enthusiastic, and closely related to higher-order thinking skills or level 6 in the Bloom Taxonomy. PBL leads to constructive,

contextual, realistic, open learning via tutorials (Zadok, 2020), which means that educators only function as the facilitator and as the supervisors in this process.

The educators' role in project-based learning is as a facilitator/connector. Projects are more authentic, demonstrating real objectives, and closely related to the sources of real-life problems. Educators are responsible for creating a learning environment in which students have the opportunities to experience learning and working. They are responsible for assisting their students to understand how to learn, learning from different perspectives, making learning sources available, and directing their students to be able to apply the knowledge they have acquired optimally.

The objective of GST is to help students, so that they become independent, accountable, harmonious, and focused on completing those projects assigned to them (Latham & Locke, 2006). Educators do not give instructions fully, but they provide information on where their students can access learning references and information about how to use the tools required in the projects. In this case, educators do not dictate to students, or dominate the exchange between them and their students, but they are more like supervisors. In other words, the learning process should not be delivered as a lecture; but it should be providing opportunities for students to ask questions, by offering solutions, and debating with their peers, and defending their analysis.

In PBL, educators function as mentors, guides, resources for students, and managers of long-term projects. PBL provides opportunities for students to develop themselves professionally, to follow all the steps in the learning process, by being fully involved, and to contribute to supporting the vision and the mission of IT Del Faculty of Biotechnology. Del benefits from this business collaboration; because PBL facilitates a unique and direct relationship between industries and their needs. PBL supports the curriculum and the learning process of bioprocess engineering, in order to gain the relevant knowledge, skills, and experience. PBL forces students to complete certain tasks related to collecting information, interviews, and other cases, by developing models and solutions to certain problems, such as developing experimental procedures, finding characteristics, developing worksheets, creating reports, supervising technology in various problems related to the projects, by acquiring soft skills, such as developing and applying communication strategies with all the stakeholders of the projects (Toledano, 2019).

Viewed from a goal-setting perspective, PBL as a learning method emphasizes that learning happens from students' direct involvement, students' active participation in constructing meaning by using their ideas to learn and work. PBL as a systematic learning method, involves students in learning knowledge and skills through the structured examination of problem complexities, authentic questions, projects and assignments designed in accordance with the course syllabus (Pan et al., 2020). Usually, in PBL, students are required to apply the knowledge they have acquired, or previous prerequisite subjects, in order to produce several outcomes, such as process or product design, network code,

experimental simulation and design, and an interpretation of the prerequisite subjects. As an example, for students of Bioprocess Engineering in IT Del, if they are able to follow the course, is it possible for them to join the course without completing the prerequisite course? PBL emphasizes the process required to achieve final goals, which are the main focus of the assignment: the students' final score in the courses they take, and which they have accumulated as their Grade-Point Average (GPA).

The characteristics of PBL design in developing learning outcomes is always started with questions 5W + H; and then the students start and participate authentically in investigating the answers to the questions asked. Students explore the questions, in order to initiate the thinking process; and they apply the important ideas in bioprocess-engineering principles. With projects, students may experience a broader environment, directly involved in communities, actively participating in collaborative activities, developing problem-solving skills, and always be the first to do so (Megheirkouni, 2016). PBL brings significant benefits to students' problem-solving skills, such as conceptual understanding, learning and working performance, and course-content mastery.

Students who participate in PBL achieve higher grades, which result in higher GPA. PBL has been argued to improve academic programs related to professional competence and challenges in synergizing theory and practicum/application and between knowledge and competence (Belwal et al., 2020). Students who participate in a project may gain working skills, such as collaborative skills, managing projects, communication skills, emphatic, and professionalism, which are in line with the IT Del motto "Godliness - Conscience- Wise".

The appreciation given by the organization to the project results makes educators and students focus on learning outcomes and partnerships between universities and their local communities, such as Regency institution, in order to encourage further partnership with the community and the industries (nationwide and even global-wide). Therefore, it may be concluded that:

H1: PBL promotes students' achievement, which is shown by the students' ability to become the learning centre in SPD and EABP courses.

2.2. Problem-based learning

Problem-based learning (PrBL) is a student-centred learning approach in which an educator functions as a motivator to advise the students. PrBL requires a constructionist experiential investigation of problems. PrBL affects students' learning achievement, and it develops their skills in class, namely problem-solving, as well as creative and critical thinking. PrBL starts with providing problems to encourage students' exploration. This can be in the form of an interesting phenomenon, or an unsolved-learning experience.

PrBL allows students to improve the value of curriculum co-creation, which is in accordance with the stipulations of the study program. Students can identify relevant problems, which they then want to solve. It shows that students may also

be involved in designing curricula, and particularly student-centred curricula (SCL) (Alexiou & Paraskeva, 2020).

PrBL can be implemented by using several approaches with similarities in coherence, sequence, and roles, which are determined by the students themselves. The most commonly used PrBL framework is that of systematic-thinking flow: identifying and clarifying 5W + 1H available in the problem scenario and making sure that the problems are well-understood; defining problems through questions and by investigation (Jian, 2019); brainstorming can be used for the students to identify possible solutions or hypotheses, based on their background knowledge; students draw conclusions while identifying ideas that are not well-defined yet; in classifying possible solutions and selecting appropriate solutions.

PrBL provides patterns to define the learning objectives. Study groups, or clusters, set their learning objectives consensually; educators ensure that the learning remains focused, achievable, comprehensive, and appropriate. In independent learning (Cambra-Fierro et al., 2021; Pan et al., 2020), students collect the information relevant to the assigned learning goals. After that, groups of the students share the results of their independent learning, identifying their learning resources; while the educators assess their students' learning; and they may do an assessment per group. By goal-setting, PrBL is directed deliberately, to improve particular areas or skills, in order to provide practical and flexible tools, which can achieve strategic learning objectives.

Certain learning needs demand PrBL construction, in order to ensure balance between learning needs and learning preferences for dynamic and informal learning activities, which can be conceptualized in strategic lesson plans (Chen & Latham, 2014). Students in PrBL require a critical flow in setting their strategies, and between strategies and their execution. Learning management purpose is to create meaningful learning; since it is correlated with adaptive response patterns that support strategic learning in this setting. When PrBL is conducted, students participate in achieving the knowledge-based learning goals required to identify and develop new ideas to solve problems. Strategic PrBL lesson plans can help motivate and lead students or cluster groups.

As planned in the learning curriculum, problem-solving models for learning are known as the goal-oriented approach. Learning activities are useful for problem-solving and consultation classes. PrBL provides a structured approach for problem-solving as a learning model. Lecturers, when adopting PrBL methods in learning, are the same as those creating the role of *Tut Wuri Handayani*. *Tut Wuri Handayani*; and this is the motto of Indonesian education, which means that when the lecturer is behind, and acts as a motivator for the students in front of him, to move forward. There are times when students are at the forefront through active creativity and learning innovation. PrBL encourages social interactions that are possible for study programs, faculties, higher-education institutions, and industries, to work together to construct knowledge, to promote students' participation in the work and problem-based learning (Soini et al., 2019). PrBL has the potential to meet the need for learning development. By integrating PrBL into

the study program's activities, an integrated learning framework can be started and then evaluated. PrBL integrates individual learning, organizational learning, and that between organizations. The learning utilizes an informal learning approach, such as that of problem-solving and structured reflections (O'Brien et al., 2019).

The following is a description of how the model can be applied in students' learning. Students are encouraged to be actively identifying problems in the learning and work unit in the study program by way of structured reflection. PrBL is known as a trigger for students to find solutions to problems. The trigger is provided in such a way that it leads to an investigation. Students are encouraged to record problems in their courses' platforms and output (Singer et al., 2018).

Supporting materials, such as references, can guide students to complete each step of the problem-solving challenge. PrBL defines and clarifies problems, which can be done by asking questions and suggesting structured reflection. Brain-storming is performed collaboratively with the students, in order to discuss possible solutions. The learning goals are set by identifying what the students want to achieve from the learning. They are also asked to reflect on their learning at the end of the learning process. By learning independently, together with the literature, the students are given a possible structure, whereby they can collect information to fill the knowledge gap and to solve problems, synthesize and develop plans for implementing the problems. Consequently, it may be concluded that:

H2: the problem-based learning method promotes students' achievements, which are confirmed by their ability to be the centre of learning in SDP and EABP courses.

2.3. Student-centred transformative learning

In the cluster-learning method, there is an urgency to develop highly qualified students, who can utilize their knowledge and skills, in order to solve problems related to knowledge and real life, or to industry, in order to meet global economic challenges. Educators or instructors often focus on contemporary issues; and they tend to ignore the complex multi-disciplinary issues faced by their students. Therefore, one of the main responsibilities of educators nowadays and the challenge to be sustainable is to prepare students, who can solve problems, who can apply their knowledge, and who can collaborate with each other and become life-long learners.

There are five strategies, which could help higher education institutions to provide better learning and education (Hains & Smith, 2012):

1. helping students to have the necessary courage to express, examine, argue, and deliver ideas or solutions;
2. understanding and respecting students' feelings and developing their cognition;
3. seriously responding to the challenge of the management of emotional intelligence;

4. offering information, creative ideas, knowledge, skills, and sensitivity to students who are required to grow supportive communities; and
5. helping students to understand the meaning of life and work with the questions about life presented to them.

Together with the previously mentioned strategies, a transformation in academic practice to enhance students' development is expected, and particularly cognitive development. It is necessary to consider the urgency of meeting the demands from industry, building business and industrial partnerships, and applying academic concepts in the professional context, and by developing students both emotionally and cognitively. It is important to bear in mind that students' high cognitive skills can be affected by, but are not dependent on, their emotions.

With the above strategies, changes in academic practice are expected to improve students' development, especially in cognitive development. The learning process needs to pay attention to the importance of meeting industrial demands, building relationships with business and industry, and applying academic concepts in a professional context, in addition to the importance of developing students both emotionally and cognitively. This is important to remember because lecturers or instructors and supervisors often see higher-order cognitive skills as being influenced by, but not dependent on, students' emotions.

Student-Centred Transformative Learning can create adaptive and transformational skills for the students. In addition, the clustering scheme results in critical and evaluative self-reflection and the ability to change the perspective, the understanding and the behaviour of the group. The objective of transformative learning is aligned with the leadership framework that is adjustable and adaptive. Changing from a deductive and empirical approach to a transformative learning includes an adjustment to a problematic frame of reference into a set of assumptions and expectations related to critical thinking habits, meaningful perspectives and mindsets, and thereby making them more inclusive, discriminatory, open, reflective and emotionally capable of any change.

The reflective assessment framework supports adaptive leadership processes and goals; the framework describes the process by which students perceive and acquire knowledge and skills. The process of this transformative-student learning experience is represented in five themes, which include: (1) to challenge the mental-learning models; (2) to build trust among learners; (3) to present freedom and empowerment in the learning process; (4) to deepen the commitment to learning; and (5) to reframe oneself and the learning attitude. In addition, students' approaches to learning change throughout learning - shifting from dependence/independence towards interdependence (Haber-Curran & Tillapaugh, 2014).

Transformative SCL and PBL are driven by the students' commitment, collaboration and reflective learning processes, in which students are faced with real-world problems that are similar to the problems that they might face in learning. PBL challenges traditional approaches to teaching that emphasize what

students need to know. SCL and PBL challenge the traditional approaches to teaching, which rather emphasize what students need to know. PBL and PrBL in a way, tend to enforce students to be active and to become used to learning independently and/or building small group discussions in cluster rooms (Cui, Laugsand & Zheng, 2021). Therefore, it may be concluded that:

H3: Problem-Based Learning and Project-Based Learning methods improve the Student-Centred Transformative Learning method.

3. The Research Design

This study adopts a semi-quantitative data approach in qualitative analysis (Yi et al., 2021), taking a comparative case study of multi-teaching methods, namely Project-Based Learning (PBL) and Problem-Based Learning (PrBL). The data were collected through observation and by distributing questionnaires, using the same data-collection method as that of the Bioprocess-Study Program, the Faculty of Biotechnology, at the Del Institute of Technology, in two different subjects with a few adjustments made to special cases in class experience, both during practical and theoretical classes.

This allows for comparison and triangulation, in order to ensure the construct validity of the study. The data collection was carried out from the fifth semester in the year 2020. Two courses in the STEM cluster became the variables of analysis for this research, called the Synthesis and Process Design (SPD) course and the Economic Analysis of the Bioprocess Projects (EABP). The method implementation in both courses was planned and supervised respectively by the Dean of the faculty, the Head of the study program; and they were specifically supervised by a supervising lecturer. Since the lecturers received the SPD and EABP Teaching Assignments, they adjusted the syllabi to the PBL and PrBL methods. Then they grouped students into two groups, according to the method in each course. During the class that lasts for one semester, the lecturer observed the learning practices and the results. The researchers obtained the data from the lecturers, who were directly involved; and they then conducted participatory observations (Luth-Hanssen, Fougner, & Debesay, 2020).

To obtain valid data, apart from distributing questionnaires to clusters of the lecturers, FGDs were also held, in order to discuss cluster activities, learning methods, assessment methods, the number of students per group, and the learning strategies. Thereafter, the benefits for the students and the lecturers were also discussed. Consequently, cluster correlation with the learning methods and achievements could thereby be obtained.

The data-collection method is carried out in several stages, as has been done in previous studies (Konrad, Wiek & Barth (2021), with some adjustments to the educational conduct in the Faculty of Biotechnology, as mentioned in Table 1.

Table 1. Data collection in the two methods of the sustainability courses

Methods	Specific applications	Covered aspects
Observations	Class sessions (3 sessions) Student-team meetings (3 hours) Instructor-team meetings (2 sessions) Dean and stakeholder meetings (2 hours) Stakeholder engagement events (2 hours) Cultural context (continuous)	External researcher's perspective on: Processes in Teaching and learning; environment in Teaching and learning; Dispositions and performances of students; and Other data collection including the institutional and cultural contexts
Interviews	Individual students; Individual instructors; Individual stakeholders; Group interviews of SPD and EABP Class	Emic perspectives on: Processes in Teaching and learning; Environment in Teaching and learning; Dispositions and performances of students; and Other data collection including the institutional and cultural contexts
Focus groups discussion	Individual team (2 hours); Across teams of SPD and EABP Class (2 hours)	Students' reflections on the following: Processes in Teaching and learning; Environment in Teaching and learning; and Teaching and learning outcomes (Concluded data collection)
Questionnaire	Learning processes in the tracking of teams both in and outside of class (continuous); Session of Collective reflection (the conduct is combined with focus group)	Students' emic perspectives on: Processes in Teaching and learning; Environment in Teaching and learning; and Outcomes in Teaching and learning (Concluded data collection and provided opportunity for reflection)

Determining and analyzing the most appropriate learning methods for the STEM cluster of the Faculty of Biotechnology, Bioprocess Engineering Study Program were done by focusing on the courses of SPD and EABP. At the beginning of the study, observations were made on the preparation and implementation of classes, including in the dormitories, classrooms, laboratories and other faculty environments that might affect the scheduling and implementation of educational, training and experimental activities. Observation results showed the clusters, learning methods, assessment methods, the number of students and the learning strategies.

Thereafter, it was continued with interviews to FGDs, in order to ensure a unified understanding of the 5W+1H (Who, What, When, Where, Whom and How) of the learning methods in the STEM cluster. SPD and EABP courses are chosen and adjusted, in order to represent STEM clusters. In the final stage, the data were completed by the distribution of the questionnaires.

Thereafter, open questions were given to the lecturers from two classes (SPD and EABP) to ensure the level of student analysis in answering what learning methods had contributed the most in improving their academic achievement. The answers to these questions would then form the basis for evaluating and assessing the most appropriate learning processes and methods for the clusters and the students.

Table 2. Open-Ended Questions from the Learning-to-Learn Course Evaluation

No.	Question
1.	How can the assessment method used show the achievement of the course objectives?
2.	What is the average percentage of the number of students who can achieve all course objectives when the SPD/EABP is self-taught?
3.	What is the average percentage of the number of students who can achieve all course objectives when the SPD is taught in a cluster with EABP (and vice versa)?
4.	If the number of students who reach CPMK have not reached 100%, what strategy has been carried out, or will be carried out, by the lecturers in the cluster to increase the percentage of the number of students who are able to achieve all the course objectives?
5.	In your opinion, what is the relation between course objectives achievement and the scores obtained by the students in the SPD and EABP course clusters?

Based on the questions above, it was found that the condition of the learning process for the SPD and EABP courses described was as follows:

Table 3. Learning Activities on SPD and EABP

No.	Activity	SPD	EABP	Learning Outcomes
1.	Learning methods during independent class	Small Group Discussion	Small Group Discussion	100%
2.	Learning methods during EABP implementation in the SPD cluster	Small Group Discussion		100%
3.	Learning methods during EABP implementation in the SPD cluster		Collaboration	100%
4.	Assessment method during the implementation of SPD in the EABP cluster	Report, Interview		100%
5.	Learning methods during EABP implementation in the SPD cluster		Report	100%

4. The Results

4.1. Learning Methods in the STEM cluster

The results showed that the PBL and PrBL methods were the methods appropriate in the STEM cluster. In addition, both the PBL and the PrBL methods showed designs that are equally capable of improving the learning performance. Thus, recommendations for other courses and/or in other clusters could use PBL and PrBL simultaneously.

The results of the analysis also showed several findings from the data analysis on how students experienced the learning process in the SPD and in the EABP cluster. Firstly, the STEM cluster through two SPD and EABP courses was proven to be able to shift the learning methods from traditional (lecturers or supervisors as learning centres) to a new, transformative model, in which the students became the centre of the learning process; and the learning outcomes became superior and competitive. In the case study, two courses grouped in one cluster, and both using the PBL and PrBL methods, thereby making students able to increase their motivation to study independently.

Moreover, lecturers and supervisors/instructors provided students with the necessary flexibility to focus on their own process, without waiting for instructions from the supervisor. PBL and PrBL allowed SCL learning models, in which the students, being at the core of the learning itself, experienced it for themselves, discovering their own process, building self-confidence, finding freedom and self-empowerment by exploring the potential that exists within themselves, deepening their commitment to learning, and designing their own learning pattern. In addition, three key stages of learning were discussed by the students, including being more independent learners, understanding that it is necessary to collaborate and to discuss with other students, in order to be able to improve themselves, whereby they indicated an increase in their academic score. Thus, hypotheses 1 and 2 are confirmed and proven.

Both PBL and PrBL are innovative and radical strategies that eventually become learning trends that emphasize improving and optimizing learning outcomes because they are student-centred, contextual, integrated and able to promote independent learning, collaboration, and reflective learning (Silva et al., 2018). PBL and PrBL learning methods are likely to be influenced by the cluster environment and are likely to be implemented in a group of subjects. The characteristics of PBL and PRBL integrated in a cluster scheme are that students are encouraged to be creative, innovative, independent and collaborative. Instructions or information from the lecturer only serve to guide the students for discussion or learning. Finally, the process becomes a valuable condition required, in order to get the best results. Process and outcome-oriented learning should motivate the students to become life-long learners.

As for the learning process, lecturers/supervisors informed the students to prepare group reports, with the following information included: problem description, definition of the cause of the problem, and hypotheses to help understand the cause of the problem. A number of techniques can be used to

describe the definition of plans, such as the 5W+1H method (Silva et al., 2018). Group reflection is necessary upon the proposed solution. At this stage, the group elaborated the difficulties encountered in the problem-solving process. Reflection should reveal the factors that accommodate or hamper the group activities. The group also needed to answer the critical questions, and to suggest a suitable solution to the problem in the project.

Since transformative SCL reflects the context, the learning activities and the learning processes, in addition to the student-centred notion; therefore, the students have full responsibility for the learning, as well as for setting goals and for the learning and evaluation processes. In the application of a student-centred approach, it is necessary to use issues relevant to the curriculum and course syllabus, within relevant topics related to industries. Understanding student perspectives and addressing previous student experiences are also necessary in transformative SCL. Consequently, this permits curriculum and syllabus adaptation, as required for the students.

Transformative SCL principles also focus on innovative abilities and on the sense of learning innovation, student interaction, and assessment. Transformative SCL facilitates learning by providing wide opportunities for students to be involved in decision-making on the learning objectives, content, activities and assessments. Students set their own learning goals and ways to actualize them, as stated by the Goal-Setting Theory (Locke & Latha, 2006):

1. Students' willingness to learn and collaborate to achieve learning goals is one of the main keys to learning motivation.
2. Clear, specific, and uneasy goals are a more-substantial driving factor than easy, general, and unclear goals.
3. Specific and clear goals lead to greater output and better performance.
4. Learning objectives must be realistic and in accordance with the syllabus.
5. Transformative SCL promotes self-pride for students and boosts their self-confidence, in order to render it possible for them to achieve their goals.
6. Avoiding misunderstanding of the expected objectives is necessary. This can be achieved by setting unambiguous, measurable and clear goals and setting a reasonable deadline for each learning objective.
7. The more challenging the goal, the better the result, and the greater the enthusiasm of students for achieving it.

For students, feedback serves as a way to indicate their achievement - reflected by their GPA and to gain rewards, as well as wider opportunities in pursuing a future career. In addition, how lecturers or supervisors adjust their relations with students is a determining factor to examine to what extent SCL is implemented (Sabah & Du, 2018). Based on the meta-analysis, the relationship between students and lecturers in the cluster remained student-centred. Thus hypothesis 3 is confirmed, in which Problem-Based Learning and Project-Based Learning methods can improve the Student-Centred Transformative-Learning method.

4.2. Learning outcomes and teaching methods

The learning process in higher education recommends effective and efficient teaching methods. The teaching aims to learn and avoid the division of learning and teaching (Yu, 2017); while learning management aims to develop the capacity of clustering in planning and managing learning and improving professional development, and to produce excellent graduates, as the mission of the institute (Singer-Brodowski et al., 2018). These teaching methods are promoted by the institute, in order to guide the transformation of students (Singer-Brodowski et al., 2018). As the saying goes "Feeding fish to someone will only feed him for a day; but teaching him how to fish will serve him for a lifetime". This proves that the PBL and PrBL learning methods can create transformative SCL values.

The purpose of the learning method is to disseminate the latest and the most advanced knowledge, in order to develop the ability to initiate ideas and use information, to develop students' ability to test ideas, and to prove them (Perander, Londen & Holm, 2020), in order to develop students' ability to generate ideas and evidence, to facilitate the development of students' personalities, and to develop students' capacity to plan and manage their own learning.

5. Discussion

Strategies in Learning Management

PBL and PrBL are able to synthesize teaching-learning strategic constructionism that was applied within the two courses. Each case shows which, as well as how many, teaching and learning strategies have been applied. In addition, PBL and PrBL methods distinguish teaching strategies from learning strategies. This study has identified that this strategy is not limited to the design of SPD and EABP; because it can also be applied to the courses in one cluster (Saghafi, 2020); and therefore, it is likely to be implemented in other clusters or fields as well.

The most appropriate teaching-method strategies, as discussed in the results of this study, are the PBL and PrBL learning methods. Both of these methods succeeded in bringing students to apply transformative SCL and in connecting theoretical courses with practicums, and completing within one semester with excellent results, as evidenced by the achievement of a high GPA. PBL and PrBL are able to be integrated in the same semester, or in different semesters in parallel, or in a series of relationships between courses, to compare two courses by using two lecturers in a team approach, and by connecting theoretical subjects to practice, as well as by applying the same topic/project/case to both subjects: as indicated, integrating knowledge and skills can occur in other STEM clusters.

Both methods support the classroom atmosphere and discussion (Jennings, 2002); and learning outcomes embody the purpose of an integrated curriculum and pedagogical level by applying the appropriate teaching/learning strategies of two courses that serve as models for other courses under a systemic level of organization and delivery of curriculum and syllabus by educators and their interrelationships, as in a collaborative team.

The most important learning strategy is interaction, where students become the central issue and the focus, and where students actively participate in the learning process of transformative SCL. This suggests that the emphasis in the strategy process should be on developing a culture of thinking; that is, it should focus on creating an intellectually stimulating environment, by asking provocative questions and by encouraging students' responsibility to construct their own learning constructs (Vänttinen & Pyhältö, 2009).

This type of knowledge stimulation involves not only individual learning, but also participation in which the lecturer with the study program deliberately promotes active and shared learning. Therefore, students would consider themselves as agents of renewal in the learning community. This condition would develop a successful mindset in dealing with changes and in implementing innovation in studies. This shows that strategic management must encourage and empower students. Moreover, study programs are expected to be collaborative, active and to involve independent-oriented learners.

This also requires the school management, including the Dean and the study program coordinators, to impart their role as a motivator (*Tut Wuri Handayani*), as members of the learning community who benefit and master the art of active learning – both as part of their professional expertise, and as a skill to be developed amongst the local teaching staff.

The findings of this study indicate that the PBL and PrBL methods are the main methods for developing students' interpersonal competence, which leads to the transformative SCL method; because some learning processes require students to be focused, active, confident, communicative and independent. The findings show that projects in class or practicum make students feel that they have an active role in solving problems, and that there are problems that must be resolved within a specific time-frame.

The findings on collaborative attitudes facilitate lecturers and students to further develop their knowledge and interpersonal skills. This may apply even beyond the development of interpersonal competence in SPD and EABP learning. Sustainability of project-based clusters has been proven to develop students' core competencies in sustainability, with increasing GPA and further course requirements.

This study goes further, by firstly identifying and describing a conducive learning process (related to the teaching methods) and, secondly, by highlighting the importance of collaboration and transformative student-centred learning (SCL) (Belwal et al., 2020). A collaborative attitude encourages the development of other key competencies, such as those applied in classroom settings, communication and solutions. This study found that the problem and project-based teaching method allowed students to develop and strengthen the SCL method, thereby creating group knowledge. The collaboration model has been proven to be able to make students learn independently, as well as in groups. Teamwork that can be

applied later, helps to develop cluster skills and attitudes. Consulting and coaching have the same effect.

In addition, external factors, such as selected student groups with high motivation, the time pressure and stakeholder policy can encourage learning competencies, according to the cluster method.

6. Conclusion

This study presents cluster management with the emphasis on PBL and PrBL methods, when using student-centred transformative learning in bioprocess engineering. Grouping, based on clusters in STEM, allows the learning process to be more focused; and it facilitates the determination of the best learning methods to improve learning performance and student achievement. Improvement of learning performance can be seen in the collaborative attitudes that facilitate lecturers and students to further develop knowledge and interpersonal skills; while student achievement is found when students participate actively in solving problems that must be resolved within a specific time-frame.

In addition, by emphasizing goal-setting through the PBL and PrBL methods, a complete track record is created, and in the end, it can be used easily during the study program accreditation process through cluster-development activities. The PBL and PrBL methods show that students actually enjoy learning and learning more. These methods create students who are able to achieve learning objectives, which are not only suitable for cluster development, but also for developing students as individuals. PBL and PrBL methods in STEM clusters show that learning can improve proactive performance. The main contribution of this research is to present an efficient learning-management scheme based on cluster grouping, and to establish a method with students as the centre, designed in PBL and PrBL patterns, in bioprocess engineering.

7. Recommendations

7.1. Theoretical implications

The Goal-setting theory is able to cover PBL and PrBL, in order to focus on transformative SCL. GST separates learning goals (because they focus more on goals), and in some ways to combine the learning goals with the performance goals.

For example, starting with the learning goals; and then, secondly, combining the performance goals, continuing with the different types of goal-framing (success versus avoidance of approaches) and joining the goals and the cognition, including all cognitive psychology, goal hierarchies, and macro-goals with clusters, or between individuals, as implied.

7.2. Practical implications

This research has documented the indications of PBL and PrBL learning methods to render students more focused and independent, which is acknowledged by the transformative SCL method. The interaction between students in the SPD and EABP courses, and in the same cluster, indicates the transfer of information and an increase in students' motivation.

7.3. Limitations and future research

This research is limited to two SPD and EABP courses in one cluster. The limitation of the research sample causes this research very likely to be obsessed by the ideal learning method. Therefore, future research should be conducted, when practised on a larger sample in a university, for the better development of learning methods.

8. Acknowledgments

The authors would like to thank Euro-Asian Collaboration for Enhancing the STEM Education (EASTEM) Project for funding this research and to the Del Institute of Technology for their full support in conducting this research.

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