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Investigation of Student Engagement in Project Based Learning on Motivation and Satisfaction: A Case Study in Making Lesson Plans on Temperature and Heat

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ABSTRACT

This study aims to determine the behaviour and involvement of students in project-based learning (PBL) in the teacher certification program at the Indonesian Education University as an indicator of success in making lesson plans on temperature and heat. This study collected relevant empirical data through the provision of questionnaires, interviews, product analysis (lesson plans) and self-assessment rubrics to students registered in the teacher certification program at the Indonesian Education University in 2024. The results of the study indicate that there is a significant influence between student involvement in project-based learning on student motivation and satisfaction in participating in learning. The analysis of heat and hydrolysis in the lesson plan that has been made is in accordance with the selection of selected indicators. The impact and evaluation of this study will be used to redesign PBL learning at UPI to improve student behavior and involvement.

1. Introduction

Growing research shows that project-based learning (PBL) in higher education is effective in preparing students with the skills needed to succeed in today's complex and rapidly evolving world [1]. The strategy is claimed to be effective in strengthening students' creative problem-solving skills, enabling students to actively research open real-world scenarios to build practical solutions to problems, increasing student collaboration, and encouraging students to read and discuss complex and real things. World events to foster critical thinking and reflective judgment [1-5]. PBL supports students to work in groups to actively build their knowledge through the 'reorganization of their previously acquired mental structures' [6]. The research shows that student behavior and involvement in PBL significantly influences student academic performance [7,8].

The implementation of PBL is a fulfilment of Indonesian government regulations: (i) Law Number 20 of 2003, concerning the National Education System, (ii) Law Number 12 of 2012, concerning Higher

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Education. (iii) Government Regulation no. 04 of 2014 concerning Management of Higher Education (iv) Presidential Regulation no. 8 of 2012 concerning National Qualification Standards. Policies issued by the government require that learning must be focused on student learning (student-center). The student-centred policy was strengthened by the launch of a new curriculum called "Mandiri Curriculum" or "Independent Curriculum". Since the launch of the Merdeka Curriculum in 2022, the use of PBL in higher education has become a must for all learning in Indonesian higher education.

Recent research has explored the benefits and challenges of PBL in higher education, highlighting the multifaceted benefits of both PBL, including enhanced student engagement [9]. Investigating students' engagement in their learning is crucial for several reasons: (a) High levels of student engagement is associated with increased academic achievement [10]. Investigating students' engagement can help identify strategies and interventions to enhance their learning experiences, leading to improved academic performance; (b) engaged students are more likely to be intrinsically motivated, demonstrate autonomy and show sense of ownership over their learning. Investigating engagement can provide insight into students' motivation and inform instructional approaches that foster intrinsic motivation; (c) higher levels of student engagement is associated with better social-emotional well-being [11]. Investigating engagement can help identify factors that contribute to students' well-being, such as positive relationships with peers and teachers, and create a supportive learning environment; (d) Understanding individual differences in engagement can help tailor teaching strategies, content, and assessments to meet students' specific needs and interests, and thus inform personalized instruction [12-14]; (e) and contribute to educational policy and practice [13,15]. Evidence-based practices derived from engagement research can inform decision-making at the classroom, school, and district levels, ultimately improving educational outcomes. In short, student engagement is central to the success of PBL. By fostering active engagement, educators can cultivate a dynamic learning environment where students develop a deeper understanding, gain key skills, and achieve strong learning outcomes.

Teacher certification is a government program run at several universities, including UPI. This program is given to in-service teachers to improve competency in teaching. As part of the UPI program, the use of PBL in the learning process of teacher certification programs must be promoted and has been implemented since the program was launched in 2018. However, there has been no substantial research investigating student learning behavior and engagement. the teacher certification program that implements PBL has not been implemented. Therefore, the investigation of this topic is relevant and urgent. Student engagement correlates with student performance in class [16], in short student behavior and engagement determine student learning success. Table 1 shows several studies that discuss student engagement, student motivation and student satisfaction in project-based learning [17-33]. The results of the analysis of several studies show that using the project-based learning model enables students to explore real-world issues by working on projects that require the integration of knowledge across various subjects, making it particularly effective in increasing engagement, motivation, and satisfaction. PBL have been suggested as promoting the acquisition of various knowledge, abilities and attitudes [34]. By carefully planning, executing projects, and finding solutions to problems, students are observed to develop their analytical and synthesis skills, as well as their critical and higher-order thinking [35]. PBL are claimed to foster discipline, goal setting, planning, and organization [36]. Furthermore, by collaborating in teams, students can improve their collaborative, social, and communication skills [37].

Difference from other studies our research gap are conducted an investigation on student engagement in project-based learning, analyzed the relationship between student motivation and student satisfaction, there was a specific analysis on the products made by students in the form of lesson plans that specifically discussed temperature and heat, and focuses on investigating the role

of student engagement in PBL within the context of teaching the concepts of temperature and heat. Specifically, the research examines how engaging students in the process of creating lesson plans on these scientific concepts influences their motivation and satisfaction with the learning process. Given that temperature and heat are fundamental topics in science education, exploring how project-based learning strategies can enhance students' understanding and interest in these topics offers valuable insights into the broader effectiveness of PBL.

Table 1
Previous Research about student engagement, student motivation and student satisfaction

No.	Tittle	Ref.
1.	The Impact of the Online Project-Based Learning on Students' Communication, Engagement, Motivation, and Academic Achievement	[17]
2.	The effect of project-based learning on learning motivation and problem-solving ability of vocational high school students	[18]
3.	Examining the impact of case-based learning on student engagement, learning motivation and learning performance among university students	[19]
4.	Using random forests to identify factors of student motivation in a project-based learning course.	[20]
5.	Unpacking High School Students' Motivational Influences in Project-Based Learning	[21]
6	Implementation of a project-based engineering school: increasing student motivation and relevant learning	[22]
7	Impact of Work and Project-Based Learning Models on Learning Outcomes and Motivation of Vocational High School Students	[23]
8	E-learning: Direct effect of student learning effectiveness and engagement through project-based learning, team cohesion, and flipped learning during the COVID-19 pandemic	[24]
9	Student motivations as predictors of high-level cognitions in project-based classrooms	[25]
10	The effect of educational games on learning outcomes, student motivation, engagement and satisfaction	[26]
11	The hybrid Project-Based Learning–Flipped Classroom: A design project module redesigned to foster learning and engagement	[27]
12	Students' extrinsic and intrinsic motivation improvements in learning defense engineering based on project-based learning	[28]
13	The positive relationship between flipped and blended learning and student engagement, performance and satisfaction	[29]
14	Social media and e-portfolios: Impacting design students' motivation through project-based learning	[30]
15	Project-based learning activities and EFL students' productive skills in English	[31]
16	Engaging students in learning: findings from a study of project-led education	[32]
17	Academic satisfaction with hospitality and tourism education in Macao: The influence of active learning, academic motivation, and student engagement	[33]

The aim of this study is to assess the levels of student engagement during a project-based learning activity, while also evaluating how this engagement impacts motivation and satisfaction. The novelties in this paper, namely: (i) one of the primary issues that many educational institutions face is the challenge of keeping students engaged; (ii) by focusing on a case study of students designing lesson plans related to temperature and heat, this research provides a deeper understanding of the practical applications of PBL; (iii) as well as its potential to improve students' educational experiences in science classrooms, (iv) Through this investigation, the study seeks to contribute to the ongoing conversation about the integration of project-based learning in enhancing student outcomes; and (v) particularly in scientific disciplines where student motivation and satisfaction can sometimes be challenging to maintain.

The research questions in this paper have three questions, namely: (i) What is learning behavior and student engagement in PBL at teacher certification program? (ii) How do learning behavior and student engagement compare in the three courses using PBL?; and (iii) How does student engagement influence project-based learning on student motivation and satisfaction in participating

in learning?; and (iv) how is the process of activities and materials designed by students as a product of lectures on temperature and heat material?

2. Literature Review

2.1 Project Based Learning

PBL is a dynamic and engaging approach that fosters deeper learning and skill development [38]. By tackling real-world problems, students learn how to apply their knowledge, work collaboratively, and develop critical thinking skills. Though it can present challenges in terms of time, resources, and assessment, PBL has proven to be a highly effective way to prepare students for both academic and professional success in the 21st century. PBL is an instructional method that encourages students to learn by actively engaging in real-world, meaningful projects. In this approach, students are given the autonomy to investigate, explore and solve complex problems, rather than being passive recipients of information. The PBL process typically involves collaboration, critical thinking, creativity, and hands-on experiences, allowing learners to deepen their understanding of the subject matter [39]. The origins of PBL can be traced back to educational reformers such as John Dewey, who emphasized the importance of learning through experience. Over the years, it has gained popularity across various educational levels, from elementary schools to universities, as an effective way to foster deep learning and enhance students' skills.

Figure 1 shows that PBL is defined by several core characteristics, namely: (i) Real-World Problems: PBL tasks are centered on solving real-world challenges, which makes learning relevant and authentic; (ii) Student-Centered Approach: Unlike traditional teacher-directed methods, PBL puts students in the role of active problem solvers and decision-makers; (iii) Collaboration: Students often work in teams, learning to communicate, negotiate and collaborate effectively. (iv) Interdisciplinary Learning: PBL encourages students to integrate knowledge from different subjects, promoting a holistic understanding of complex topics; (v) Reflection: Students are encouraged to reflect on their learning process and outcomes, which helps them gain metacognitive insights; and (vi) Presentation of Results: At the end of the project, students typically present their findings, further enhancing their public speaking and communication skills.

The literature highlights numerous benefits of PBL: (i) Enhanced critical thinking and problem-solving skills: Because PBL challenges students to tackle complex issues, it promotes higher-order thinking and helps develop problem-solving strategies [40]; (ii) Improved Engagement and Motivation: PBL often results in greater student engagement, as the projects are seen as more relevant and meaningful. The process allows for student agency, which can increase motivation [41]; (iii) Collaboration and Communication Skills: By working in teams, students develop important interpersonal skills, including collaboration, communication and leadership [42]; (iv) Long-Term Retention: PBL has been found to lead to better long-term retention of knowledge. This is due to the active engagement with the material, which enhances memory and understanding; (v) Interdisciplinary Learning: PBL allows students to draw connections between different areas of study, helping them see the relevance of their education across subjects.

PBL offers an engaging and effective approach to education that empowers students to take charge of their learning through real-world challenges [43]. The literature supports its potential to enhance critical thinking, problem-solving and collaboration skills, while also promoting deep, interdisciplinary learning. However, challenges such as time constraints, assessment issues, and the need for teacher training must be addressed for its successful implementation. As educational contexts continue to evolve, PBL remains a powerful tool for preparing students for the complex demands of the modern world.

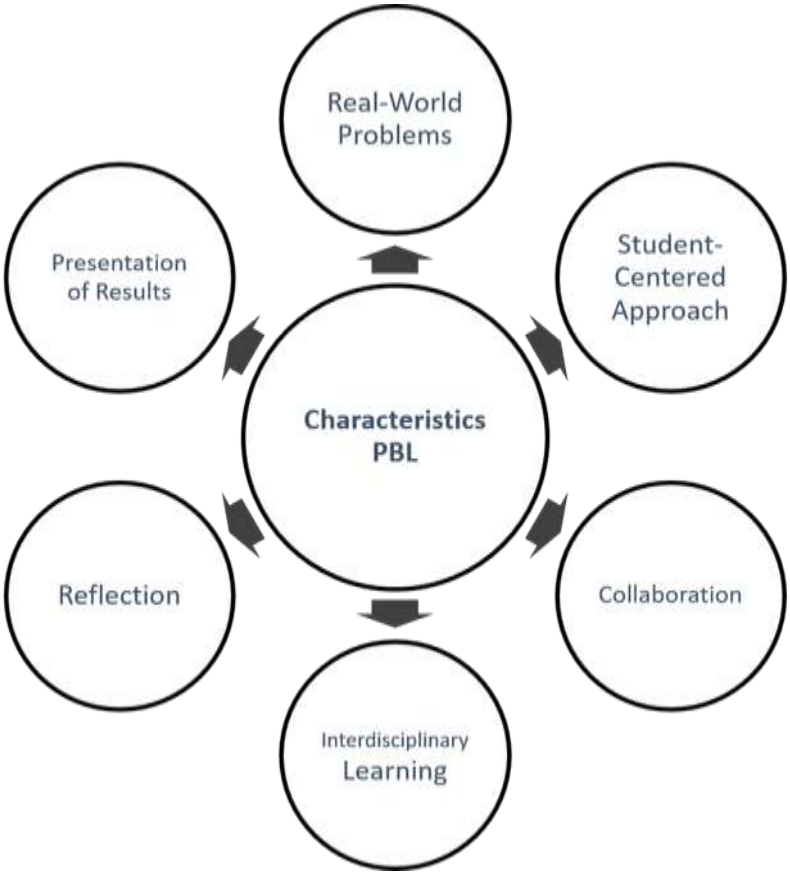


Fig. 1. Characteristics project-based learning (PBL)

2.2 Motivation and Satisfaction

Satisfaction and motivation are two critical psychological factors that significantly impact students' learning experiences and outcomes [44]. Understanding how these factors interact can help educators create environments that foster better engagement, learning and achievement. Motivation refers to the internal drive or desire that prompts students to engage in learning activities, pursue goals, and persist in the face of challenges. Motivation plays a crucial role in determining how much effort a student is willing to invest in their learning. Satisfaction refers to the student's overall sense of contentment or fulfilment with their learning experience. It is closely tied to how students perceive their learning environment, the quality of their interactions with teachers and peers, and the relevance of the material. Motivation and satisfaction are key factors influencing students' academic experiences, behaviors, and outcomes. Motivation refers to the internal drive that initiates, guides, and sustains students' efforts toward achieving academic goals. Satisfaction, on the other hand, pertains to the degree to which students' expectations and needs are met in the educational environment. Both motivation and satisfaction are vital components of student learning and have profound implications for academic performance, retention, and overall well-being.

Motivation theories are central to understanding how students engage with their studies. Several prominent theories have emerged, including: (i) Self-determination theory (SDT) distinguishes between intrinsic and extrinsic motivation. Intrinsic motivation arises from an inherent interest or enjoyment in the task, while extrinsic motivation is driven by external rewards or pressures. In educational contexts, students who experience autonomy, competence, and relatedness are more likely to be intrinsically motivated; (ii) Expertancy-value theory: According to Eccles and Wigfield [74], students' motivation is influenced by their expectations of success and the value they place on

a task. If students believe they can succeed and find the task meaningful, they are more likely to engage and persist. This theory highlights how students' subjective assessments of their abilities and the relevance of their studies influence their academic motivation; (iii) Goal-orientation theory: suggests that students' motivation can be influenced by their goal orientations. Students may adopt a mastery goal (focused on learning and improvement) or a performance goal (focused on proving ability relative to others). Those with mastery goals tend to experience greater satisfaction because they view challenges as opportunities for growth, while performance-oriented students may be more sensitive to failures and less satisfied with their educational experiences; and (iv) Students' motivation is influenced by how they attribute their successes and failures. If students attribute academic success to internal, controllable factors (such as effort), they are more likely to maintain high levels of motivation and satisfaction. Conversely, attributing failure to uncontrollable or external factors (e.g., luck, task difficulty) can lead to decreased motivation and dissatisfaction.

Various individual, social and environmental factors play a role in shaping student motivation: (i) Individual Factors, they are Self-Efficacy and interest and enjoyment. The importance of self-efficacy, or belief in one's ability to succeed. Students with high self-efficacy are more motivated, set higher academic goals, and experience greater satisfaction. Students are more motivated and satisfied when they find the subject matter interesting and enjoyable. Intrinsic motivation is particularly high when students are passionate about the content being taught; (ii) Teacher-Related Factors, they are: Teaching Style and Support also teacher student relationships. Research has shown that a supportive and engaging teaching style can significantly enhance student motivation and satisfaction. Teachers who provide timely feedback, foster a positive learning environment and encourage student autonomy tend to motivate students more effectively. Positive teacher-student relationships have been found to improve both motivation and satisfaction. When students feel valued and respected by their teachers, they are more likely to engage with the learning process; (iii) Peer interactions play a critical role in motivation. Collaborative learning environments, where students work together to solve problems or complete tasks, can foster motivation and increase satisfaction. Peer support can also alleviate academic stress and enhance social connections, leading to a more satisfying learning experience; and (iv) Environmental and Institutional Factors, namely: Learning Environment and curriculum and assessment: The physical and psychological aspects of the learning environment, such as classroom design, technology availability, and the overall school culture, can impact motivation and satisfaction. An environment that promotes autonomy. creativity and student participation tends to enhance both motivation and satisfaction; A well-structured curriculum that aligns with students' interests and goals is important for motivation. Additionally, formative assessments that encourage learning and improvement, rather than solely focusing on grading, can contribute to higher levels of student satisfaction [45].

The relationship between motivation and satisfaction is bidirectional. Motivated students are more likely to experience higher satisfaction because they actively engage with their learning, find meaning in their academic pursuits, and achieve success [46]. Conversely, students who are satisfied with their academic experiences tend to be more motivated, as satisfaction fosters positive emotions and encourages further engagement with learning tasks. Several studies have shown that motivation and satisfaction are strongly linked to academic achievement.

Motivation and satisfaction are crucial factors that influence students' learning experiences and outcomes. Motivation is driven by a variety of individual, teacher-related, and environmental factors, while satisfaction is shaped by the alignment of students' needs and expectations with their academic experiences. A positive relationship exists between motivation and satisfaction, and both factors are associated with better academic performance. Educational institutions can enhance student motivation and satisfaction by fostering supportive environments, providing autonomy, and

encouraging meaningful interactions. Future research should continue to explore the dynamic interplay between these factors to better inform instructional practices and policies in education.

2.3 Student Engagement

Student engagement refers to the level of involvement, enthusiasm, and commitment that students exhibit toward their learning and educational experiences [47]. It is considered a critical factor for academic success, as engaged students are more likely to participate actively in the learning process, demonstrate better academic performance, and show higher levels of satisfaction with their educational experiences. The concept of student engagement encompasses a variety of dimensions, including behavioral, emotional and cognitive engagement. Over the past few decades, extensive research has explored the factors that influence student engagement, its relationship with academic achievement, and the role of educational practices in fostering engagement. This literature review aims to provide an overview of key theories, dimensions and factors influencing student engagement, as well as its impact on student outcomes. Student engagement is generally understood as a multi-dimensional construct that includes several key components [48], namely: (i) Behavioral Engagement: Behavioral engagement refers to the degree to which students participate in academic and extracurricular activities. It includes actions such as attending classes, completing assignments, engaging in discussions, and collaborating with peers. Behavioral engagement is often seen as a strong indicator of students' investment in their learning; (ii) Emotional Engagement: Emotional engagement relates to students' feelings toward their learning experiences, including their interest, enthusiasm, and emotional connection to the subject matter, teachers and peers. Students who feel emotionally engaged are more likely to develop a positive attitude toward school, leading to higher motivation and persistence; and (iii) Cognitive Engagement: Cognitive engagement involves the intellectual effort students put into their learning. It includes deep thinking, self-regulation, goal-setting, and the use of metacognitive strategies to understand and master the content. Cognitively engaged students are not only focused on completing tasks but are also motivated by intrinsic goals such as understanding, mastery, and self-improvement.

Several theoretical frameworks have been proposed to understand the concept of student engagement. These include:

i. The Investment Model of Engagement: The investment model posits that students invest time and effort in their learning when they perceive the value of doing so. This model emphasizes that engagement is influenced by students' perceptions of the relevance and importance of their academic tasks and their intrinsic motivation to learn [49].
ii. Self-Determination Theory (SDT): Suggests that student engagement is influenced by the degree to which students' basic psychological needs for autonomy, competence, and relatedness are met. When students feel that they have control over their learning (autonomy), believe they are capable of succeeding (competence), and experience positive relationships with peers and teachers (relatedness) [50].
iii. Flow Theory: Concept of "flow" describes a state of deep immersion and focus in an activity, where students are fully absorbed in their learning tasks. In this state, students experience high levels of cognitive engagement, and their motivation is intrinsically driven. Flow is most likely to occur when students are challenged just beyond their current abilities, leading to a balance between skill and task difficulty [51].

iv. Community of Practice (CoP): Engagement is influenced by students' participation in a community where knowledge is shared and constructed collaboratively [52]. This theory emphasizes the importance of social interaction, collaboration, and a shared sense of purpose in fostering engagement in learning activities.

Various factors can influence student engagement, ranging from individual characteristics to environmental and institutional elements: (i) Individual Factors, they are Motivation: Motivation is closely linked to engagement. Students who are intrinsically motivated are more likely to engage cognitively, emotionally and behaviorally in learning activities. Students with high self-efficacy, or belief in their ability to succeed, are also more likely to engage actively in their studies. (ii) Interest and Relevance: Students are more likely to engage in subjects they find interesting or relevant to their personal goals or future aspirations. The more students perceive the content as meaningful, the more engaged they tend to be; (iii) Teacher-Related Factors: Teaching strategies that promote active learning, such as collaborative projects, problem-solving activities, and inquiry-based learning, are shown to increase student engagement. Teachers who use diverse teaching methods and who create an interactive classroom environment are more likely to engage students. Positive, supportive relationships between students and teachers foster emotional and behavioral engagement. Teachers who demonstrate care, respect, and encouragement can motivate students to participate more actively in learning; (iv) Peer and Social Factors, Collaborative learning environments that encourage peer interactions, group work, and peer feedback can enhance student engagement. Social connections and the sense of belonging to a peer group are crucial for emotional engagement and motivation. Students who perceive a strong network of support from peers and teachers tend to be more engaged. Social support enhances students' feelings of safety and belonging, which in turn can increase engagement in academic and social activities; (v) Environmental and Institutional Factors, A positive school climate that promotes respect, inclusivity, and a sense of community can foster higher levels of engagement. Schools that emphasize student voice, autonomy, and responsibility are more likely to see greater engagement. The integration of technology in the classroom, such as interactive tools, multimedia, and online platforms, can enhance engagement, particularly cognitive engagement.

Student engagement is a multifaceted concept that plays a critical role in shaping academic outcomes and overall student well-being. It is influenced by various individual, social and institutional factors, including motivation, teacher practices, peer relationships and the school environment. The literature suggests that engaged students are more likely to achieve academic success, stay in school, and develop important life skills. Educational institutions can enhance student engagement through active learning strategies, student-centered approaches, positive teacher-student relationships, and the integration of technology. As engagement continues to be a focal point in educational research, further exploration into its complex dynamics will continue to inform effective teaching and learning practices.

Student engagement, motivation and satisfaction are closely interconnected factors that significantly influence students' academic experiences and outcomes. Understanding the relationship between these three concepts is essential for improving educational practices and fostering environments that enhance learning. Below, we explore how these factors are related, and how they collectively impact students' academic success, well-being and overall educational experience.

2.4 The Influence of Satisfaction on Motivation and Engagement

While motivation drives engagement, student satisfaction can, in turn, reinforce motivation and engagement. When students feel satisfied with their educational experiences, they are more likely to: (i) Feel Empowered: Students who perceive their academic environment as supportive and rewarding are more likely to feel confident and motivated to engage in learning activities. Positive emotions related to satisfaction enhance motivation by promoting a sense of competence and self-efficacy [53]; (ii) Experience continued motivation: Satisfied students are more likely to develop a positive outlook on their academic journey, leading to sustained motivation over time [54]. When students feel that their needs and expectations are being met, they are more likely to remain motivated to persist in their studies; and (iii) Engage More Actively: Satisfaction with the learning environment encourages students to take on new challenges and participate in more academic and extracurricular activities [55]. The more satisfied students are with their educational experiences, the more likely they are to remain engaged in their studies. Therefore, student satisfaction contributes to motivation and can create a cycle of continuous engagement. As students experience positive outcomes from their engagement, their satisfaction with their academic environment grows, which in turn fosters even greater motivation and further engagement.

Figure 2 Shows about relationship between engagement, motivation, and satisfaction is reciprocal and dynamic. High levels of motivation lead to increased engagement, which, in turn, leads to greater satisfaction with the learning experience.

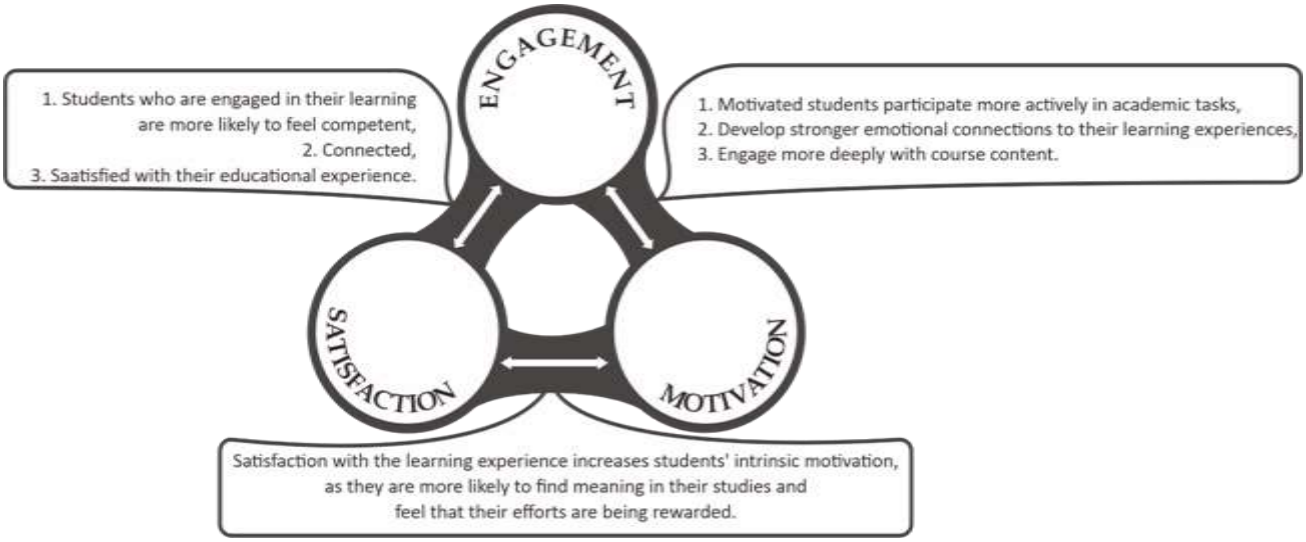


Fig. 2. Relationship between engagement, motivation and satisfaction

This satisfaction reinforces motivation, creating a positive feedback loop, Motivated students participate more actively in academic tasks, develop stronger emotional connections to their learning experiences, and engage more deeply with course content, Students who are engaged in their learning are more likely to feel competent, connected and satisfied with their educational experience, and Satisfaction with the learning experience increases students' intrinsic motivation, as they are more likely to find meaning in their studies and feel that their efforts are being rewarded. In contrast, low engagement may lead to dissatisfaction, which can decrease motivation. If students do not feel engaged in their learning, they may become less motivated, leading to a negative cycle of disengagement, low satisfaction and further lack of motivation. The relationship between student engagement, motivation, and satisfaction is complex and interdependent. Motivation serves as the foundation for engagement, which, in turn, leads to greater satisfaction with the learning experience.

Satisfaction, in turn, reinforces motivation and engagement, creating a positive cycle that enhances academic success and personal development. By understanding and leveraging these relationships, educators can create environments that promote sustained engagement, foster motivation, and increase student satisfaction, ultimately leading to better learning outcomes and overall student success.

2.5 Temperature and Heat

Temperature and heat are fundamental concepts in thermodynamics and are essential to understanding various physical, chemical and biological processes. Temperature refers to a measure of the average kinetic energy of particles in a substance, while heat is the transfer of energy from one body to another due to a temperature difference [56]. These concepts play a crucial role in fields such as physics, chemistry, biology, engineering, and environmental science.

Temperature is a scalar quantity that indicates the thermal state of matter [57,58]. It provides information about the motion of particles within a substance: the higher the temperature, the faster the particles move. The temperature scale, often expressed in degrees Celsius (°C), Fahrenheit (°F), or Kelvin (K), is essential for comparing and quantifying thermal energy in different systems. Thermal Kinetic Energy: At the microscopic level, temperature is related to the kinetic energy of atoms and molecules. According to the kinetic theory of matter, the temperature of a substance is directly proportional to the average kinetic energy of its particles. A higher temperature corresponds to faster-moving molecules, whereas lower temperatures result in slower molecular motion. Measurement of Temperature: Temperature is commonly measured using thermometers, which can be based on different physical properties, such as expansion of liquids (mercury or alcohol thermometers), electrical resistance (resistance temperature detectors), or infrared radiation (infrared thermometers). The most widely used temperature scales are Celsius, Fahrenheit, and Kelvin, with the Kelvin scale being the SI unit of temperature measurement.

Heat refers to the transfer of energy from a body at a higher temperature to one at a lower temperature [59]. Unlike temperature, which is a property of a system, heat is the energy transferred between systems or surroundings. Heat transfer occurs via three primary mechanisms: conduction, convection, and radiation. Figure 3 shows about heat transfer mechanisms.

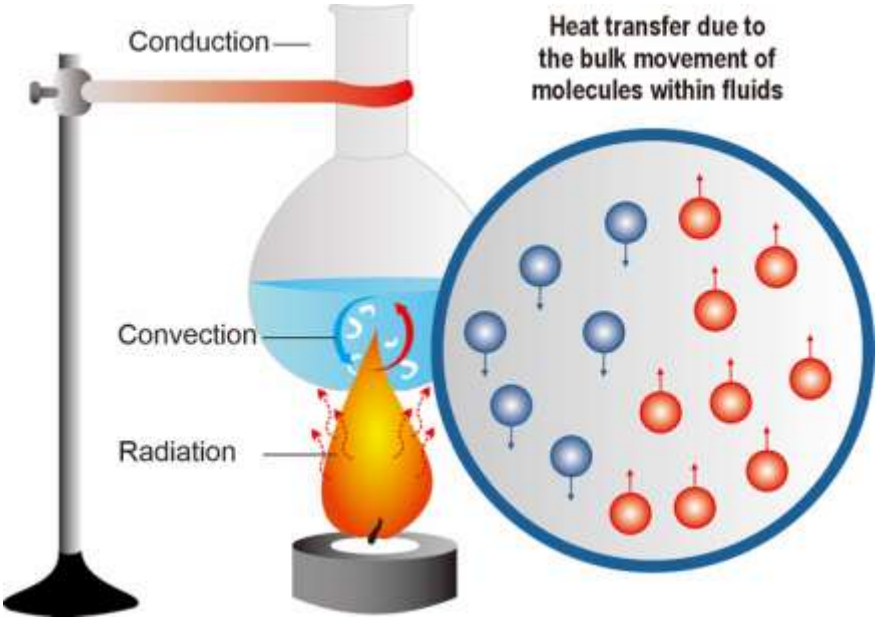


Fig. 3. Heat energy

Conduction is the transfer of heat through direct molecular interaction. It occurs in solids where particles are closely packed, and heat is transferred through vibrations of atoms and molecules. The rate of heat transfer by conduction is governed by Fourier's Law, which states that the rate of heat transfer is proportional to the temperature gradient and the material's thermal conductivity. Convection is the transfer of heat through a fluid (liquid or gas) by the movement of the fluid itself. Convection occurs due to the difference in temperature and density within the fluid. Warmer fluid becomes less dense and rises, while cooler fluid sinks, creating circulation that facilitates heat transfer. The efficiency of convective heat transfer is influenced by factors such as fluid velocity, viscosity, and temperature differences. Radiation: The transfer of heat *via* electromagnetic waves, primarily infrared radiation. All bodies emit thermal radiation, with the amount of radiation emitted increasing with temperature. The Stefan-Boltzmann Law quantifies the total energy radiated by a black body as proportional to the fourth power of its absolute temperature. Heat and Thermal Energy, while temperature is the measure of the thermal state of a system, heat refers to the energy transferred during a process due to a temperature difference. The amount of heat transferred is related to the mass, specific heat capacity, and temperature change of a substance should be written as Eq. (1), where Q is the heat, m is the mass, c is the specific heat capacity, and ΔT is the change in temperature.

$$Q = mc\Delta T \tag{1}$$

Temperature and heat are central to understanding a wide range of natural and technological processes [60]. The concepts of temperature, heat transfer mechanisms, specific heat, latent heat and the impact of temperature on material properties are fundamental in disciplines ranging from physics and engineering to biology and environmental science. The ability to control and measure temperature and heat is critical in applications such as industrial manufacturing, energy production, climate modelling and health care. As our understanding of temperature and heat continues to evolve, these principles will remain essential to the advancement of science and technology. Figure 4 explain about temperature transform, Conduction: A metal rod with one end heated. The heat moves from the hot end to the cold end through the rod, as molecules vibrate and transfer energy. Convection: Surrounding the metal rod, there is air. As the air near the rod heats up, it becomes less dense and rises. Cooler air moves in to take its place, forming convection currents, and Radiation: The metal rod also emits infrared radiation, represented by wavy lines radiating outward from its surface.

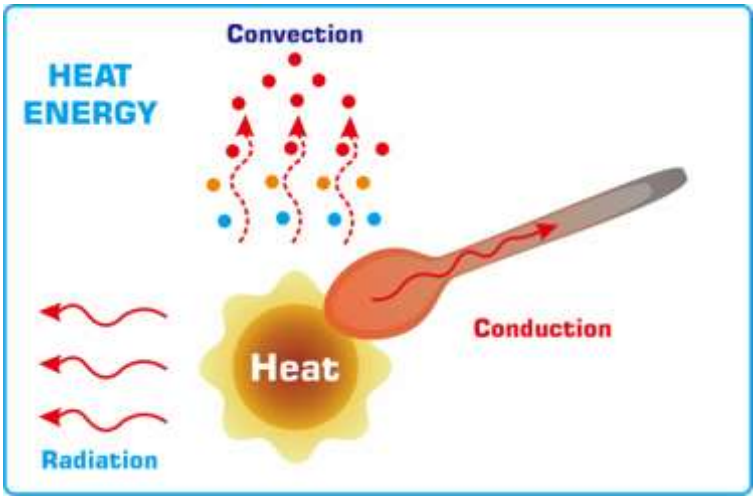


Fig. 4. Temperature transform

3. Methodology

The research conducted in six months. Figure 5 shows a research approach that begins with a literature review to identify PBL theory and identify indicators of learning behavior & student engagement. Identification of student behavior and involvement will be carried out during and after the implementation of PBL. Data collection instruments will use observation sheets, questionnaires and interview protocols. The data collection design in the research will be carried out as follows: (1) Before learning, students will be given a questionnaire to ask about motivation to take part in the teacher certification program, interest in the teaching profession. (2) During learning activities, students' behaviour will be observed in class, during group activities and when working independently. Observations are carried out to look for signs of active participation, attention and interaction with peers and teachers. Data on class assignment completion and progress over time will also be used to identify student academic performance during learning. (3) Next, a learning behaviour questionnaire will be given to collect data about students' level of interest, motivation and satisfaction with their learning experience. Self-assessment will be used to reflect their engagement by asking them to rate their level of engagement, focus, and effort in learning using a self-assessment rubric. The following data will be collected to identify student performance after learning activities: academic performance including their grades, and attendance which will be used to record student attendance records as regular attendance and punctuality are indicators of engagement.

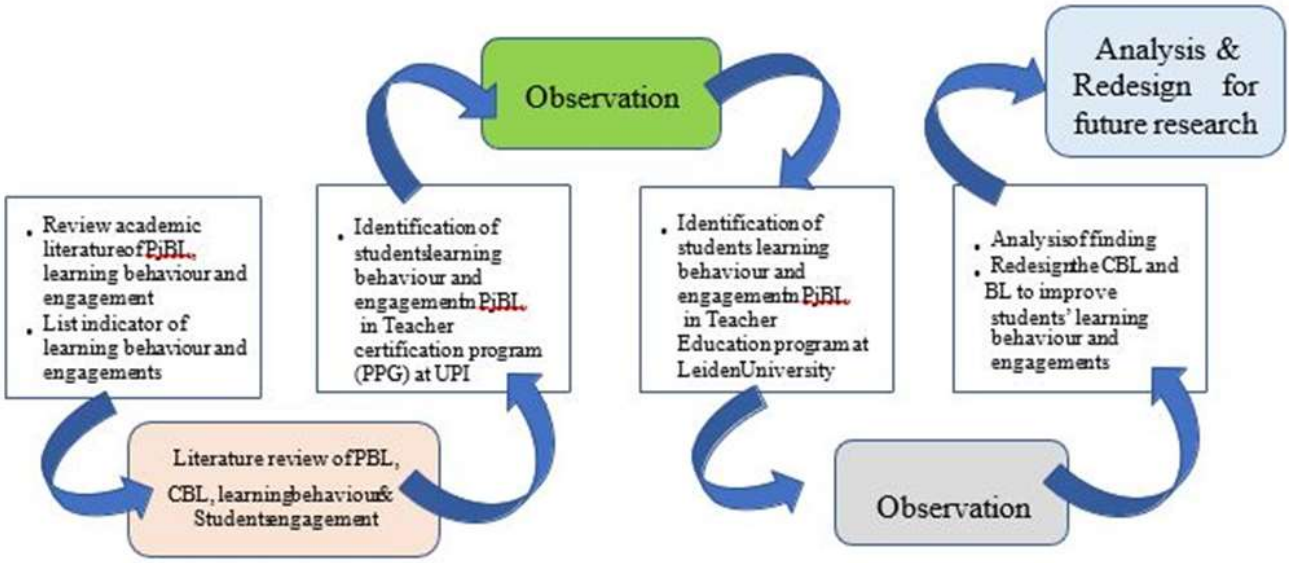


Fig. 5. Approach in solving problem of students' learning behaviour and engagement in PBL at teacher certification program (PPG) Universitas Pendidikan Indonesia

The students who were used as respondents were 102 students. Table 2 is a profile of students involved in this study, but specifically for the product of learning planning on temperature and heat, it was taken from students with science competencies. While Table 3 shows the linearity between research questions, data sources, instruments and data analysis. The instruments used are interviews, self-assessment, product analysis and questionnaires that have been validated by language experts and material experts. The data will be analyzed by triangulation from three sources as it shown in Figure 6.

Table 2
Profile of students involved in research

No.	Profil	Subject matter		
		Seminar PPG	Proyek Kepemimpinan	Desin Thinking
Age				
1	20-25	22	22	27
2	26-30	8	16	7
Competences				
1	Science	7	12	2
2	The othercounseling guidance	-	6	4
3	Mathematics	-	-	11
4	Civic education	-	-	4
5	Culinary	-	-	11
6	Art and Culture	3	3	2
7	Social Science	3	10	-
8	Indonesian	-	1	-
9	English	-	2	-
10	Mechanical Engineering	-	3	-
11	Agritechnology Processing Agricultural Products	-	1	-
12	Primary Teacher Education	17	-	-
Students/Subject		30	38	34
All Students		102		

Table 3
Research questions, source of data, instruments and data analysis

No.	Research Question	Source of Data	Instrument
1	What is learning behavior and student engagement in project-based learning (PBL) at the Indonesian Education University teacher certification program?	Students' perception of motivation, interest, and learning experiences, active participation, attentiveness, and interaction with peers and teachers	Observation sheet: - Interview protocol - Questionaries
2	How do learning behavior and student engagement compare in the three courses using PBL?;	Students' perception of motivation, interest, and learning experiences in three courses using PBL	Observation sheet: - Interview protocol - Questionaries
3	How does student engagement influence project-based learning on student motivation and satisfaction in participating in learning?	Students' motivation, interest, and learning experiences, active participation, attentiveness, and interaction with peers and teachers	Observation sheet - Interview Protocol - Questionaries
4	How is the process of activities and materials designed by students as a product of lectures on temperature and heat material?	Explain about process activity and material from lesson plan that design by student with the temperature and heat material	Rubric analysis lesson plan about process activity and material in the lesson plan

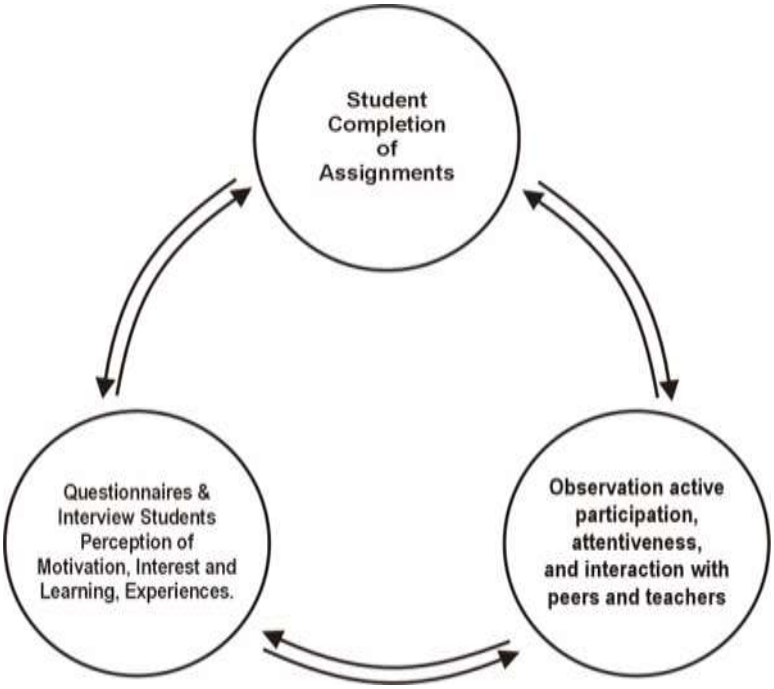


Fig. 6. Data triangulation

4. Results and Discussion

4.1 Results

Table 4 shows several questions given to students to find out initial data as a diagnostic test regarding the implementation of PBL learning that students have participated in, as well as some data regarding teaching experience and the effectiveness of implementing learning using PBL in PPG lectures. Based on Table 4, it can be seen that respondents provided information about their experiences in using PBL, where from the three courses more than 50% answered that they had used PBL several times in learning before participating in PPG activities. From the results of their experience using PBL, it was reported that they got the most experience when receiving education while pursuing undergraduate or strata 1 education. This shows that the university where they studied education greatly influenced the results of the experience they got [61]. The choice of place of education greatly influences the quality of the graduates' results [62]. In the third question, the results showed that the participants who attended lectures at PPG were dominated by teachers who had only taught for less than one year and could be said to be young teachers before attending PPG. The implementation of these three courses is said to be very suitable using the LMS, so that the teaching material and assignments presented in the LMS are stated to be useful for respondents in implementing all courses at PPG. This states that the role of teaching materials and evaluation or assessment is very important in supporting the implementation of learning, which technically is included in the form of an LMS [63].

Table 4
Initial question

No.	Initial question	Criteria	Seminar PPG		Proyek Kepemimpinan		Design Thinking	
			Result	%	Result	%	Result	%
1	Have you ever experienced learning through PBL before you joined the PPG program?	Often	9	30%	11	29%	8	24%
		Several time	18	60%	17	45%	19	56%
		Once	1	3%	7	18%	6	18%
		Never	2	7%	3	8%	1	3%
2	If the answer to number 1 is "Yes", where do you get learning through PBL?	While studying undergraduate	26	86%	33	87%	30	88%
		PPG	2	7%	3	8%	3	9%
		Never	2	7%	2	5%	1	3%
3	How long did you teach before joining PPG?	0 year	7	23%	10	26%	13	38%
		< 1 year	11	37%	17	45%	11	32%
		1-2 year	8	27%	8	21%	10	29%
		> 2 years	4	13%	3	8%	0	0%
4	Does the lecturer teach the material according to the flow presented in the LMS?	very suitable	10	33%	7	18%	11	32%
		Suitable	19	63%	21	55%	20	59%
		slightly appropriate	1	3%	10	26%	3	9%
5	In your opinion, does the material presented in the LMS help you understand the lecture material?	Very helpful	14	47%	13	34%	9	26%
		Help	14	47%	11	29%	17	50%
		A little help	2	7%	14	37%	8	24%
6	In your opinion, do the assignments on the LMS help you in attending lectures?	Very helpful	10	33%	11	29%	8	24%
		Help	18	60%	13	34%	18	53%
		A little help	2	7%	10	26%	6	18%
		less helpful	0	0%	4	11%	1	3%
		doesn't help at all	0	0%	0	0%	1	3%

4.1.1 What is learning behavior and student engagement in PBL at the Universitas Pendidikan Indonesia teacher certification program?

In answering the first research question, namely "What is learning behavior and student engagement in PBL at the Indonesian Education University teacher certification program?", it can be seen in Figure 7 that the results show the learning behavior and student engagement obtained using PBL learning in three courses, the highest results were obtained in the response of agreeing for the three variables, namely: student engagement, student satisfaction, and motivation, and the lowest score was obtained in the response of strongly disagreeing for each indicator of the three variables. This shows that the learning behavior for participants who take part in PBL learning is very well applied to grow student engagement, student satisfaction, and student motivation in participating in learning activities. This is in accordance with research results which show that PBL can increase student engagement, student satisfaction, and student motivation [64-66].

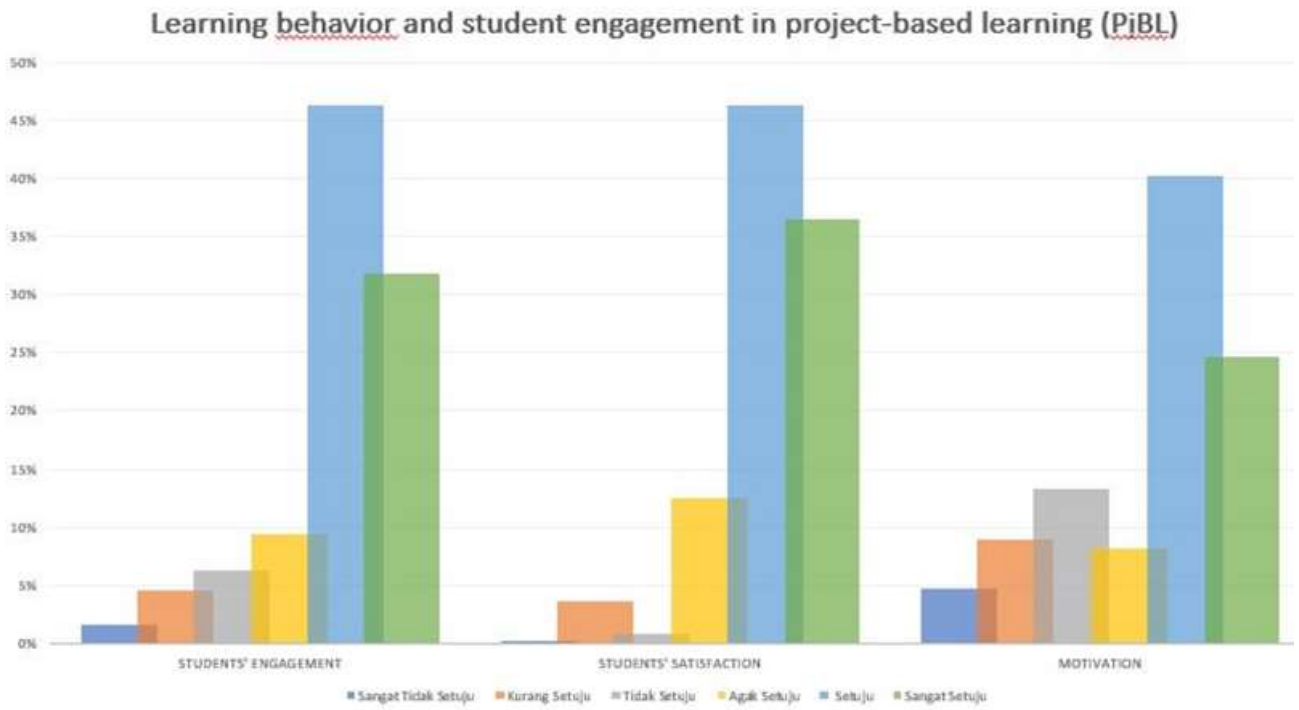


Fig. 7. Learning behaviour and student engagement in PBL

4.1.2. How do learning behavior and student engagement compare in the three courses using PBL?

In answering the second research question, namely "How do learning behavior and student engagement compare in the three courses using PBL?". it can be seen in Figure 8 that the results show for a comparison of learning behavior and student engagement from the three courses, namely PPG seminar courses, learning projects and design thinking. Almost all indicators have the highest agree response value compared to other responses, except for the leadership project course where the student satisfaction indicator shows that the value of the strongly agree response is greater than the agree response. This shows that PBL is also consistently able to provide positive responses to learning behavior and student engagement, especially on the indicators of student engagement, student satisfaction and student motivation. Especially in courses that are directly connected to projects, PBL is very suitable for increasing student satisfaction. This is in line with several studies that discuss the suitability of selecting PBL for learning with appropriate themes such as project and design bases [67-69].

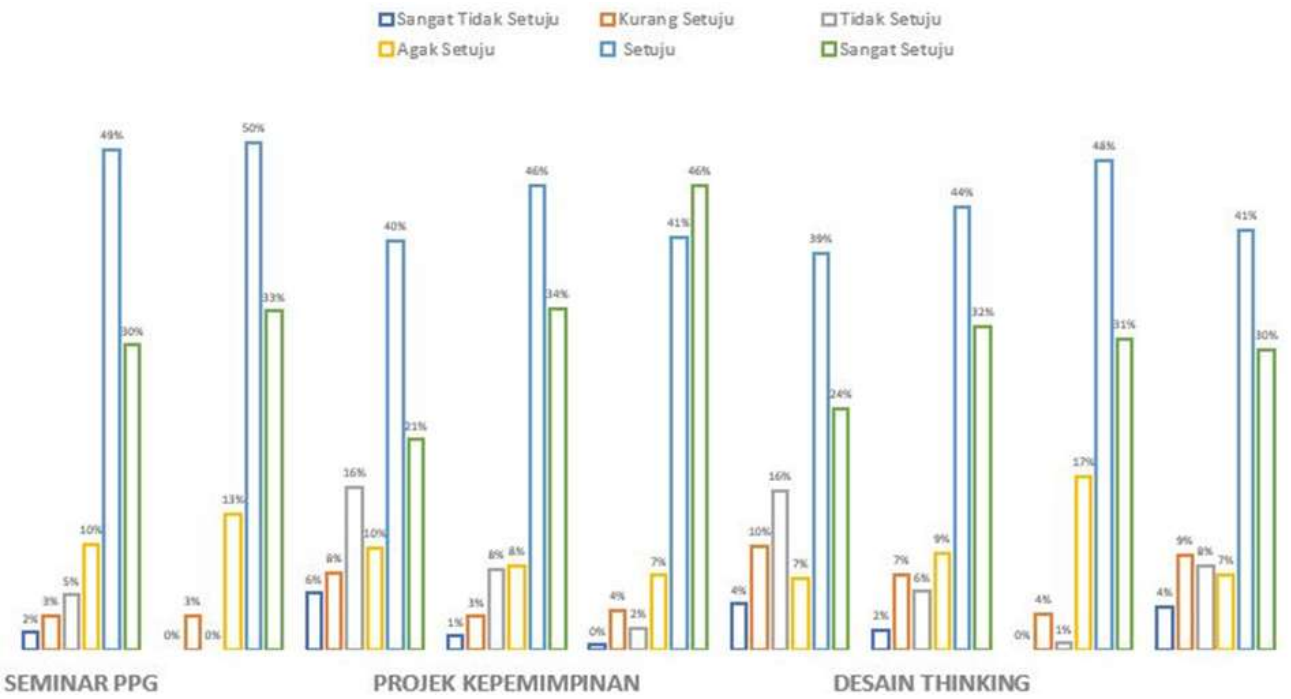


Fig. 8. Learning behaviour and student engagement compare for three courses using PBL

4.1.3 How does student engagement influence project-based learning on student motivation and satisfaction in participating in learning?

In answering the third research question, namely "How does student engagement influence project-based learning on student motivation and satisfaction in participating in learning?". it can be seen in Figures 9 and 10 for the normality data and then discussed in Tables 5, 6 and 7 for the effect results. Either in the histogram image which shows that the data distribution in the middle is greater than the distribution of data on the right and left, this shows the data is normally distributed, or seen in the straight line in Figure 10 shows the linearity of the data distribution, which also shows the data is normally distributed. Therefore, from this normally distributed data, further analysis can be carried out for the F test, T test and regression to see whether or not there is an influence from PBL on student engagement, student satisfaction or motivation. Table 5 shows the statistical values of the respondent data, where the table explains that the number of respondents in this study was 102 respondents, with a minimum value of 3.5846 which indicates a somewhat agree value, and a maximum value of 5.7086 which indicates an agree and agree value. almost the value is close to strongly agree, with an average value of 4.9706 in the agree statement category. Meanwhile, the standard deviation value is 0.40712.

Table 6 shows the significance coefficient value of the influence of student engagement on learning using PBL on student satisfaction and motivation. Where the resulting value is sig. < 0.05, namely sig. 0.000, this shows that there is a significant positive influence of student engagement using PBL in learning on student satisfaction and motivation scores. However, if we compare the effects separately, it can be seen in the second and third rows, where the results show sig. (0.000) < 0.05 for student satisfaction, which means there is a significant positive influence of student engagement in PBL on student satisfaction. Likewise with the sig value. (0.020) < 0.05 which shows that there is a positive influence of student engagement in PBL on student motivation. The results of the F test simultaneously or together can be seen in Table 7, where the sig value. (0.000) < 0.05 which shows that there is a significant influence on student engagement in PBL which is applied to the learning process on student satisfaction and motivation. These results are in accordance with the

statement that there is a strong influence between students' behavior in participating in learning well and the level of confidence and motivation they gain after participating in learning using PBL [30].

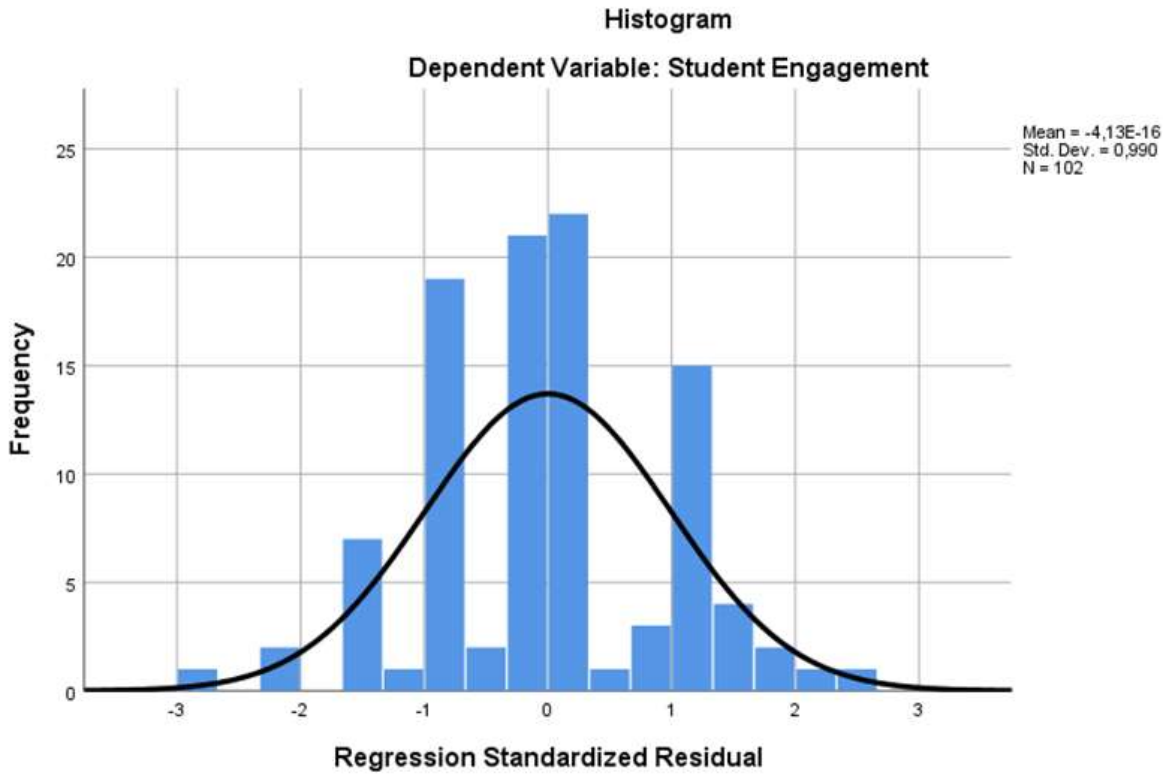


Fig. 9. Histogram about regression standardized residual

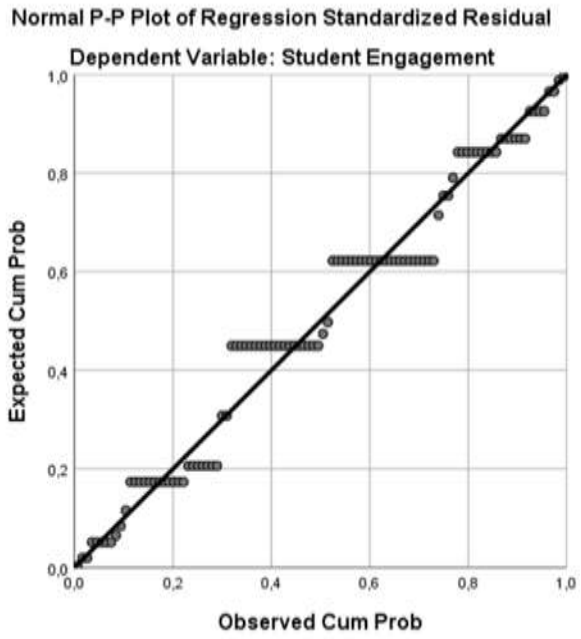


Fig. 10. Normality P-P Plot of regression standardized residual

Table 5
Residual's statistics

	Min.	Max.	Mean	Std. Deviation	N
Predicted value	3,5846	5,7086	4,9706	,40712	102
Residual	-1,42158	1,35342	,00000	,50904	102
Std. predicted value	-3,404	1,813	,000	1,000	102
Std. residual	-2,765	2,632	,000	,990	102

a. Dependent Variable: Student Engagement

Table 6
Coefficients significancy the effect of student engagement in project-based learning on motivation and satisfaction student in learning

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	1,848	,429		4,310	,000
	Student Satisfaction	,419	,071	,510	5,878	,000
	Motivation	,225	,095	,204	2,357	,020

a. Dependent Variable: Student Engagement

Table 7
ANOVA for effect of student engagement in project-based learning on motivation and satisfaction student in learning

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	16,740	2	8,370	31,662	,000[b]
	Residual	26,172	99	,264		
	Total	42,912	101			

a. Dependent Variable: Student Engagement
b. Predictors: (Constant), Motivation, Student Satisfaction

The correlation value or magnitude of the influence of student engagement in project-based learning on student motivation and satisfaction in learning have *R* value 62.5%, there is a strong relationship between student engagement and student satisfaction and motivation, while the remaining 37.5% has a strong relationship between student engagement and other variables. Likewise, the value of the influence of student engagement on student satisfaction and motivation, seen from the R square value, shows a value of 39%, while the rest has an influence on other variables. In fact, this value is still considered very small because it is still below 50% of the influence that student engagement has on student satisfaction and motivation. Therefore, further research is needed to see a stronger influence on other variables.

4.1.4 How is the process of activities and materials designed by students as a product of lectures on temperature and heat material?

The process of activities and materials designed by students as a product of lectures on temperature and heat involves the application of theoretical concepts learned during the lecture to create tangible projects or experiments. Several factors are important points in making a learning plan that must be considered, including understanding core concepts, engagement and problem-solving, designing materials, experimentation and data collection, reflection and reporting peer learning and feedback. In summary, the process of activities and materials designed by students as a product of lectures on temperature and heat is cantered around the application of learned concepts in real-world scenarios. It encourages problem-solving, experimentation and critical thinking,

allowing students to actively engage with the principles of temperature and heat while fostering deeper understanding through hands-on experience. Figures 11-15 Shows the process of activities made by students in the learning process plan, where there are 5 activities that are planned to be carried out with details of the material discussed in each meeting including:

(i) First meeting discusses the concept of temperature and temperature measurement, at this meeting students are introduced to the basics of the concept of temperature, where students are directed contextually to feel the differences felt in three different water conditions, until students are able to distinguish water conditions with different temperatures in real terms that are felt by the hand and the temperature value directly using the measuring instrument that has been taught (Figure 11);

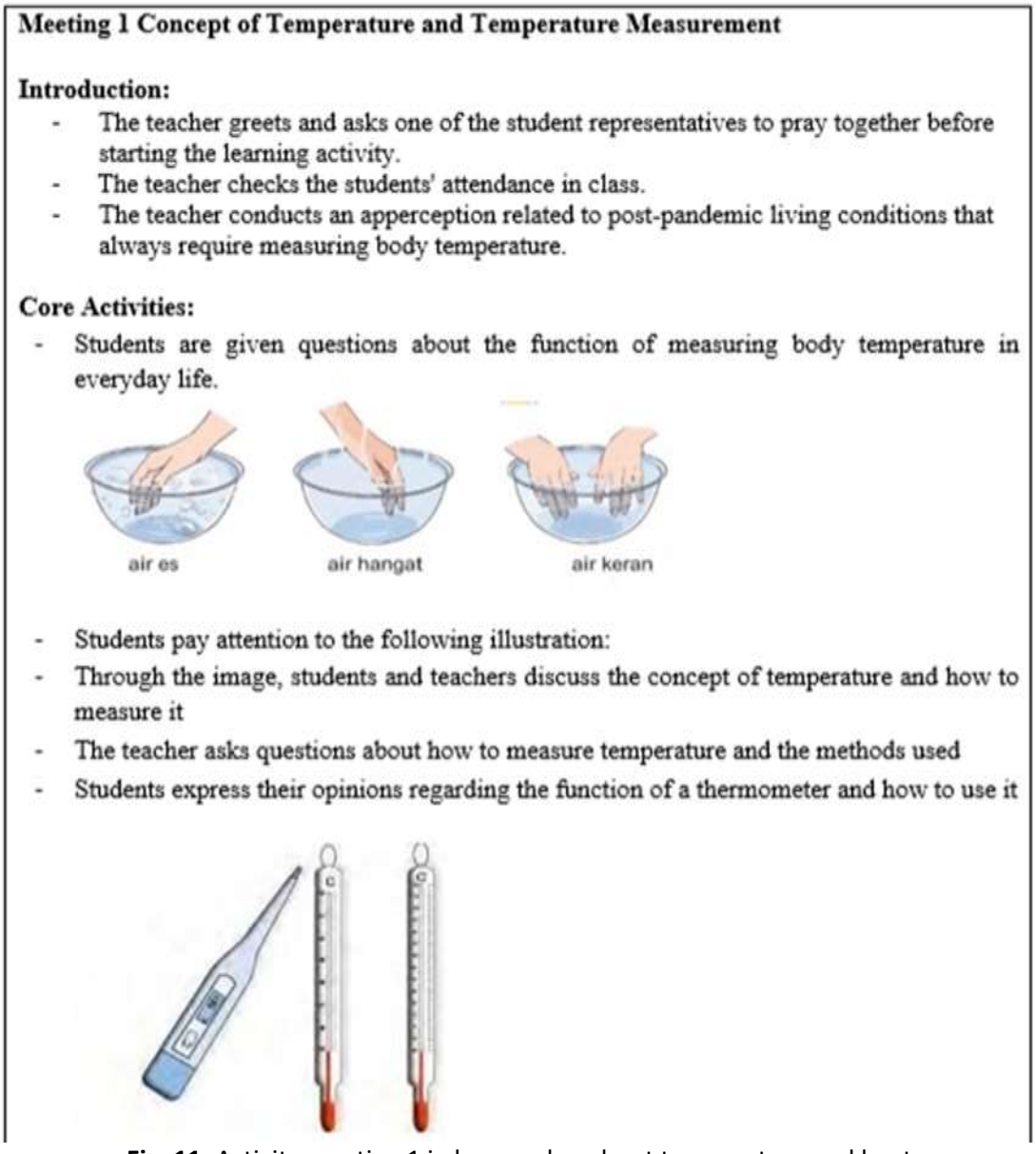


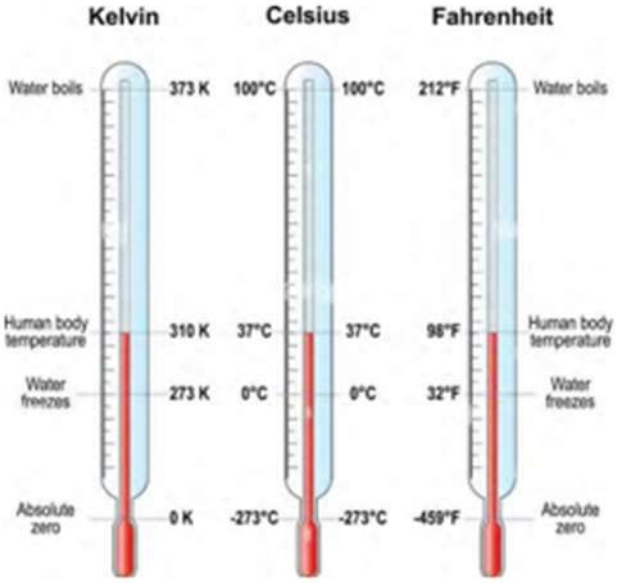
Fig. 11. Activity meeting 1 in lesson plan about temperature and heat

(ii) Second activity students are taught about the concept of temperature conversion, in this activity, students can already measure temperature and then students are taught to convert temperature values from three thermometers with different temperature units, namely Celsius, Kelvin, and Fahrenheit (Figure 12);

Meeting 2. Temperature Conversion

Introduction:

- The teacher greets and asks one of the student representatives to pray together before starting the learning activity.
- The teacher checks the students' attendance in class.
- Students are grouped based on their needs and learning styles.
- The teacher presents a picture or video about the differences in commonly used thermometer scales (Celsius, Reamur, Fahrenheit, and Kelvin). https://youtu.be/9xdwMJO0sQk?si=kc7CHovXrVhFTzwJ



Core Activities:

- The teacher shows the differences in intervals and comparisons of the scale values of the four thermometers.
- The teacher gives examples of calculating temperature values for the four thermometer scales using comparison values.
- Students discuss in groups that have been determined with the teacher based on the differences in students' prerequisite abilities (students who understand the learning

Fig. 12. Activity in 2nd meeting

(iii) The third meeting students are taught about the concept of heat and specific heat, where students are given stimulus using a video about the condition of a person who is near a campfire, then students are expected to be able to understand the basic concept of the definition of heat, and students are also directed to the material on specific heat through a contextual comparison of asphalt and water conditions, so that students are expected to be able to understand the difference in specific heat in each material (Figure 13);

(iv) The fourth meeting discussed the material on calculating heat by providing several problems related to the use of heat energy with several variables that were associated, namely mass, specific heat and temperature changes (Figure 14);

Meeting 3. The concept of heat and specific heat

Introduction:

- The teacher greets and asks one of the student representatives to pray together before starting the learning activity
- The teacher checks the students' attendance in class
- The teacher shows a picture or video of someone who is near a campfire and then asks: "When around a campfire, what will the person's body feel?"

Core activities:

- The teacher explains the concept of heat by giving questions for students to discuss about what happens to the human body when it is in a hot or cold area
- Students and the teacher discuss in class how heat energy can move from objects or places with high temperatures to objects or places with lower temperatures

- The teacher again gave questions about the difference in heat between water and asphalt during the day as a stimulus for students to discuss the concept of specific heat.

Fig. 13. Activity in the 3rd meeting

(v) The fifth meeting discussed the types of changes in heat energy that were closely related to everyday life in a contextual manner. The Evaluation section discussed in the learning plan made by students about temperature and heat is given a questionnaire for self-assessment, then formative questions and worksheets that aim to enable students to distinguish the types of changes in heat energy in several conditions (see Fig. 15). The Figure 16 shows the assessment as sheet for evaluation.

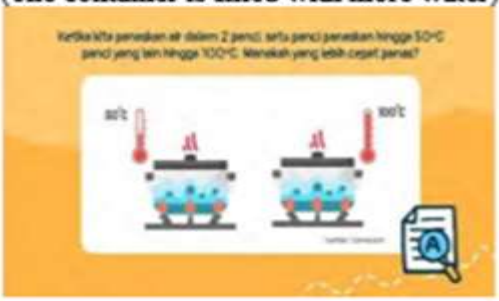
Meeting 4. Calculating the amount of heat

Introduction

- Teacher The teacher greets and asks one of the student representatives to pray together before starting the learning activity.
- The teacher checks the students' attendance in class.
- The teacher reviews the previous material related to heat energy that moves from objects/places with high temperatures to objects/places with lower temperatures.

Core activities:

- The teacher presents a demonstration video of heating water in two different containers (one container is filled with more water)



- The teacher presents a demonstration video of heating water in two different containers (one container is filled with more water).
- Students with teacher guidance analyze that the amount of heat is influenced by three factors: 1) mass of the object; specific heat of the object; and the temperature change that occurs. Formula for Calculating Heat:
- Q = m.c.AT
- The teacher provides an example of using the formula for the amount of heat and how to calculate it.
- Student's practice calculating the amount of heat through questions provided by the teacher.
- The teacher guides and facilitates learning difficulties according to the ability and development of the learning process

Closing Activities:

- Student representatives try to show the results of the large heat calculations in front of the class.
- The teacher provides reinforcement of learning outcomes.

Fig. 14. Activity in the 4th meeting

4.2. Discussion

4.2.1 Learning behavior and student engagement in PBL

The results of the first research question indicate that PBL effectively fosters positive learning behavior, student engagement, student satisfaction and motivation. The data, as depicted in Figure 3, show that the highest levels of engagement were achieved in the "agree" responses across the three variables: student engagement, satisfaction, and motivation, while the lowest responses were from those who "strongly disagreed." This pattern is significant as it reflects the success of PBL in encouraging active participation, motivation and overall satisfaction with the learning process. The findings align with previous research suggesting that PBL enhances student engagement, satisfaction, and motivation by creating an active and collaborative learning environment that encourages critical thinking, problem-solving, and hands-on learning experiences [70].

The strong engagement in PBL suggests that students are not merely passive recipients of information but actively involved in their learning, which is essential for developing deeper understanding and long-term retention. This result highlights the effectiveness of PBL in stimulating positive academic behaviors, such as initiative and collaboration, which are crucial for teacher education programs like the Indonesian Education University teacher certification program.

Meeting 5. Heat Transfer

Introduction:

- The teacher greets and asks one of the student representatives to pray together before starting the learning activity.
- The teacher checks the students' attendance in class.
- The teacher groups students into 4 or 5 groups based on a combination of students with complementary characteristics and learning abilities.
- The teacher shows a picture of a frying pan that has a plastic handle as a heat retainer and invites students to discuss based on their experiences observing various heat transfer events.

Core Activities:

- The teacher reviews three heat transfer events (conduction, convection and radiation)
- Students pay attention to the animated video shown https://youtu.be/y1OkjaB5j5Q
- Students work in groups on the worksheet that has been given
- The teacher provides reinforcement during the learning process and facilitates students in each group who have learning difficulties.
- - Student representatives from the group explain the results of observations regarding heat transfer in heated metal and water.

Fig. 15. Activity in the 5th meeting

Fig. 16. Job sheet in the lesson plan

4.2.2 Comparison of learning behavior and student engagement across three courses

The second research question focuses on comparing learning behavior and student engagement across three distinct courses: PPG seminar courses, learning projects and design thinking. The results, as shown in Figure 4, indicate that the student responses across these courses were overwhelmingly positive, with "agree" being the most common response across almost all indicators of student engagement, satisfaction, and motivation. An exception was found in the leadership project course, where the "strongly agree" response was more common than "agree" for the student satisfaction indicator.

The findings suggest that PBL is particularly effective in project-based courses, where students are actively engaged in creating tangible outcomes [71]. Courses such as learning projects and design thinking appear to benefit from the hands-on, collaborative nature of PBL, reinforcing the idea that students are more motivated and satisfied when the content is relevant and connected to real-world challenges. This is consistent with prior research, which emphasizes that PBL is most effective when the course content involves meaningful projects, allowing students to apply their learning in practical and impactful ways. These results underscore the importance of selecting course themes that align with the principles of project-based learning, ensuring that the tasks and goals are relevant to students' future careers and personal interests.

4.2.3 Correlation between student engagement, motivation and satisfaction

The third research question examines the correlation between student engagement, motivation and satisfaction in PBL. According to Table 7, the R value of 62.5% suggests a strong relationship between student engagement and both student motivation and satisfaction. However, the R-squared value of 39% indicates that there are additional factors influencing student satisfaction and motivation beyond student engagement alone. This means that while engagement plays a significant role, other variables—such as teaching quality, course design and personal interest—also contribute to students' overall learning experience.

The fact that the R-squared value is below 50% suggests that further research is needed to better understand the complex relationship between these variables and identify the additional factors that may enhance the effectiveness of PBL. It is possible that variables such as peer interaction, instructor feedback, or the specific nature of the projects themselves could have an additional influence on student outcomes, warranting further exploration [72]. Nonetheless, the strong relationship between engagement and motivation/satisfaction confirms the importance of fostering an environment where students are actively involved in the learning process.

4.2.4 The role of product lesson plans in student success

Finally, the design of product lesson plans was also noted to play a significant role in students' positive experiences with PBL. The results suggest that when students are actively involved in creating meaningful projects as part of their lesson plans, they demonstrate high levels of engagement, motivation and satisfaction. This underscores the importance of careful planning and designing learning activities that not only align with course objectives but also capture students' interests and provide opportunities for creative expression and practical application.

Effective lesson planning in PBL involves clear project goals, real-world relevance and opportunities for collaboration, critical thinking and problem-solving. These elements are crucial for maintaining student engagement and satisfaction. As seen in the results, the projects designed by students in PBL, such as those in the design thinking and learning project courses, were particularly successful in fostering motivation and satisfaction. Thus, lesson plans that focus on project-based outcomes allow students to see the direct impact of their efforts, further enhancing their learning experience.

Overall, the findings from this study emphasize the effectiveness of PBL in fostering student engagement, satisfaction, and motivation, particularly in courses where projects are central to the learning process. The strong relationship between student engagement and motivation/satisfaction suggests that active learning strategies are crucial for improving educational outcomes. However, the relatively small R-squared value indicates the need for further research to identify additional factors that influence student success in PBL environments. The design and implementation of effective lesson plans that incorporate real-world projects are essential in maximizing the benefits of PBL and ensuring that students remain motivated and satisfied with their learning experiences [73].

5. Conclusion

The purpose of this study is to ascertain, as a measure of learning success, how students behave and participate in PBL in the teacher certification program. PPG seminars, leadership projects and design thinking are the three courses in question at Universitas Pendidikan Indonesia. Through the use of questionnaires, interviews and self-assessment rubrics, students enrolled in the Universitas

Pendidikan Indonesia teacher certification program in 2024 will provide pertinent empirical data for the study. The study's findings indicate that motivation and satisfaction with learning are significantly impacted by students' involvement in project-based learning. analysis of the findings, the strong link between student engagement and motivation or satisfaction highlights the importance of active learning strategies in enhancing educational outcomes. Nevertheless, the relatively low R-squared value points to the necessity of further investigation to uncover other factors affecting student success in PBL settings. Crafting and executing well-designed lesson plans that integrate real-world projects is vital for optimizing the advantages of PBL and maintaining students' motivation and satisfaction with their learning journey.

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