

Exploring students' perceptions of their learning experience and self-efficacy in online physics class with project-based learning: An interpretative phenomenological analysis

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Project-based learning (PBL), recognized as an active learning strategy, has been linked to students' self-efficacy in prior studies, including those within physics education research. Meanwhile, technological advancements have significantly facilitated the optimization of diverse learning modes, including online learning. However, comprehensive investigations addressing questions such as *how students perceive PBL and their self-efficacy, what forms of PBL design they prefer, and what benefits and challenges they encounter during its implementation* remain underexplored in existing literature. This work presents the results of 1- and 2-year pedagogical research on 10 students as preservice physics teachers in an online PBL physics class, focusing on its influence on their self-efficacy within a phenomenological study. Data were collected via semistructured, in-depth interviews. Social cognitive theory, Bandura's self-efficacy theory, and a theoretical framework for the impact of project-based learning on educational outcomes were employed as guiding frameworks to shape the interpretation of students' experiences and perspectives. Through interpretative phenomenological analysis, the researchers identified three primary themes representing the students' experiences. There are (1) variety of unique learning experiences based on students' perceptions about their character, (2) pivotal experiences as catalysts in the learning process, and (3) student self-awareness. The findings contribute novel insights for educators in implementing PBL, particularly in online contexts, by highlighting strategies to accommodate diverse student personality characteristics. Moreover, the latest findings in this study, compared with relevant research that has been done previously, are discussed. The study offers valuable references for research on the interplay between PBL and self-efficacy. Possible directions for further research are discussed.

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I. INTRODUCTION

Educators in recent decades have experimented with a variety of learning strategies to find effective ways of teaching, such as flipped learning, project-based learning, problem-based learning, and cooperative learning. The goal is to welcome the paradigm shift from teacher-centered to student-centered learning [1]. Project-based learning (PBL), as one of the four learning strategies, has received a lot of attention in the field of education [2]. The findings showed that PBL significantly improved student learning outcomes, including academic achievement, motivation, self-efficacy, and high-level thinking skills; increased student engagement in learning; and promoted

the mastery of new knowledge [3–6]. Meanwhile, technological advancements have significantly facilitated the optimization of diverse learning modes, including online learning. The application of PBL through online learning has been reported in several previous studies and shows positive indications [7,8].

PBL, recognized as an active learning strategy, has been linked to students' self-efficacy in prior studies, including those within physics education research (PER). Self-efficacy was introduced by a prominent Stanford psychologist, Albert Bandura, in his book, *Self-Efficacy: Toward a Unifying Theory of Behavioral Change*, in 1997 [9]. Self-efficacy is defined as a person's confidence in his or her ability to complete a particular set of tasks in a particular field [10]. Furthermore, Bandura provides a detailed conceptual analysis and empirical review of how self-efficacy operates in conjunction with the sociocognition represented by SCT in influencing human actions, adaptations, and changes [11]. SCT itself is a theory also introduced by Albert Bandura in 1986, drawing on many years of basic research using behaviorist and social

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learning frameworks [9]. These theories continue to have relevance in today's education field. For example, regarding adaptability, educating students to be able to adapt to future developments and face the complex real world has naturally become an important mission in education reform around the world [12,13].

Several studies have explored the implementation of PBL on students' self-efficacy. However, there remains a limitation in the reporting of previous findings, which we consider to be the novelty of this research. Based on currently available studies, some research has investigated the effect of PBL on self-efficacy and other variables [1,14–18], while others have investigated the effect of PBL on variables other than self-efficacy [16,18–20]. Furthermore, other studies have focused specifically on examining the implementation of PBL on self-efficacy [21–24]. The implementation of PBL and its relationship to other variables such as academic procrastination, science achievement, science students' attitudes, learning, critical thinking, learning engagement, cognitive skills, and core competencies [16,18–20] have also been examined, along with findings summarizing the effect of PBL on student learning effects, including emotional attitude, thinking skills, and cooperative ability [2], as well as studies combining PBL with other learning strategies [25,26].

The findings reported in these studies generally compared the achievements of student groups given PBL and those given conventional instruction (control group). The findings reported that the achievements obtained by the group of students given PBL, for example, numeracy skills and self-efficacy [14], students' achievement and self-efficacy [15], or science achievement [16], were superior to the achievements of students in the control class group. Meanwhile, Shin [1] observed student motivation and self-efficacy before and after PBL implementation and found that the average scores of the completed projects aligned with students' self-efficacy. The implementation of PBL had a positive effect on student motivation, marked by an increase in the motivational aspects measured before and after instruction. Furthermore, regarding findings on the effect of PBL on variables other than self-efficacy, Wang *et al.* [19] reported that PBL substantially improved cognitive and practical skills, as well as fostered students' critical thinking.

Research focusing on the implementation of PBL and its relationship to students' self-efficacy reported that PBL contributed positively to students' self-efficacy, shown as a statistically significant increase before and after PBL implementation [21], for example, in solving physics problems, and to student achievement [2,20,23,24]; data collected through questionnaires also showed a positive response to PBL implementation [15]. Furthermore, PBL was able to improve students' cooperation skills across different levels, grades, and ages [1,19]; increase engagement in the science environment [16]; and prove effective

when combined with other learning strategies [25,26]. Moreover, through the implementation of PBL, results showed that self-efficacy was positively correlated with creative thinking attitudes and project-based learning value [17].

In addition to these positive findings, several reports also offered recommendations for the implementation of PBL. For example, findings showed that students' attitude scores toward PBL were lower compared to their scores in learning, critical thinking, and student engagement [18], and practical implementation challenges were also identified, such as the extensive preparation time required to design and facilitate effective PBL activities for both teachers and students [19]. These findings are considered to have implications for how future PBL activities can be organized and how curricula can be developed to improve students' attitudes toward PBL.

Drawing on this body of research, several empirical data points have been obtained from the studies conducted so far. For example, in terms of research approach, previous studies employed a quantitative approach in the form of experimental or quasi-experimental research [14,15,20,23–25], survey research [1,17,18,21,22], or literature review in the form of meta-analysis [2]. Furthermore, in terms of data collection methods, previous studies reported collecting data using questionnaires and surveys [1,17,18], tests [16,18,22], or interviews [15]. This indicates that exploration through a qualitative approach to the implementation of PBL and its relationship to student self-efficacy remains limited.

The research approach in quantitative form reports the results of the study through statistical analysis based on responses to questionnaires and tests. Despite previous research attempts to gather qualitative data through interviews, the exploration of students' perceptions of PBL implementation remains limited [15]. In addition, the study has not explored students' perceptions of their self-efficacy while participating in PBL. Furthermore, in general, previous research has not detailed the projects carried out in PBL, as well as the variability of observation time ranges, such as 3 weeks, 3 months, or even 1 year. Meanwhile, some other studies have not included the duration of the observations made. One of the research suggestions in previous studies was to explore the long-term impact of PBL implementation [19].

To address this gap in the literature, this study reports the results of research involving ten students from the Physics Education Department as preservice physics teachers, examining the implementation of PBL in an online class aimed at preparing them for the teaching profession. The authors used a qualitative phenomenological approach through interpretative phenomenological analysis (IPA) [27] to discover the lived experiences of students over a period of four semesters (2 years) of instruction in order to explore questions such as *how*

students perceive PBL and their self-efficacy, what forms of PBL design they prefer, and what benefits and challenges they encounter during PBL implementation. A learning activity can appear very different to the instructor and to the students. Improving the alignment between teaching and learning requires an understanding of how students think and has proven highly beneficial as a guide for developing effective instruction [28].

The findings obtained in this study complement the results of previous studies. We believe that these findings can provide meaningful implications and knowledge contributions for teachers, preservice teachers, and curriculum policy development institutions, especially in physics education and education in general. This study is guided by the following three research questions:

RQ1: What is the student's perception of themselves and their learning experience in project-based learning?

RQ2: How is the project-based learning design that students are interested in, and how do students feel about the benefits of the projects they are working on?

RQ3: How do students perceive their self-efficacy based on their experience in project-based learning? How does PBL give meaning to each participant's reflection at the end of learning?

II. LITERATURE REVIEW

This section provides a conceptual overview of the theoretical frameworks employed in this study, namely, PBL, social cognitive theory [29], Bandura's self-efficacy theory [10], and the theoretical framework for the impact of project-based learning on educational outcomes [2]. These frameworks were used to shape the interpretation of students' experiences and perspectives, as explained in the following subsections.

A. Physics education research and project-based learning

Studies related to curriculum and learning are one of the research topics in PER [28,30–32]. Studies on the implementation of PBL in physics instruction have been reported in several studies. Espinosa [22] reported that the implementation of PBL was shown to reduce the gender gap in students' self-efficacy in an introductory physics class. Another study, by Goldstein [6], using a qualitative phenomenological approach based on grounded theory, observed preservice elementary school teachers in a fundamentals of physics class over two semesters of instruction and reported that PBL fostered meaningful learning (particularly within the scope of the project), improved students' attitudes toward physics learning, and increased students' motivation, self-efficacy, and comfort in learning throughout the course. On the other hand, Ospankulova [18] reported that students' attitude scores toward PBL were lower compared to their scores in

learning, critical thinking, and student engagement, and among the effects of PBL on learning motivation, learning attitude, learning interest, and self-efficacy, self-efficacy received the lowest influence [2]. These findings imply that further research exploration is still needed, particularly in physics education.

The PBL approach has its theoretical roots in Dewey's ideas [33], which hold that students will develop personal investment in the material if they engage in real, meaningful tasks and problems that emulate what experts do in real-world situations [34,35], as well as in Vygotsky's ideas [36] about the importance of social interaction in the learning process [6]. Krajcik and Blumenfeld [34] labeled PBL in science with the term project-based science (PBS). PBS has five key features: (1) driving questions, (2) situated inquiry, (3) collaboration, (4) learning technologies, and (5) artifacts.

Another source, Zhang and Ma [2], characterizes PBL by the presence of learning process components. These components include (1) identify project objectives and scope, (2) assign project plan, (3) implement the project, (4) monitor project progress and solve problems, and (5) complete the project and perform presentations and evaluations. In this study, the researchers generally applied the five process components outlined by Zhang and Ma [2], as well as designed learning activities synchronized with the five PBS features outlined by Krajcik and Blumenfeld [34], as presented in Fig. 1.

Zhang and Ma [2] reported a study that synthesized 66 experimental investigations on the implementation of PBL and its impact on student learning, resulting in a framework named the theoretical framework for the impact of project-based learning on educational outcomes. This framework describes five main components: process, feature, ability, moderator, and learning effect. The process component explains the implementation steps of PBL, while the feature component outlines the stimuli that can be provided in PBL implementation to optimize learning. The ability component outlines the student abilities that can be influenced when PBL implementation is optimized.

Zhang and Ma [2] found that the implementation of PBL can foster creative thinking, cooperative ability, critical thinking, and computational thinking ability. Furthermore, PBL can train problem-solving ability, decision-making ability, problem-raising ability, and comprehensive ability. In addition, through PBL, several abilities can be enhanced, specifically learning attitude, learning interest, learning motivation, and self-efficacy. In the moderator component, the variables regarded as moderators related to the implementation of PBL on learning effect are outlined. These include subject category, course type, learning section, experimental period, experimental scale, and country and region. Finally, the learning effect component consists of thinking skills, academic achievement, and emotional attitude.

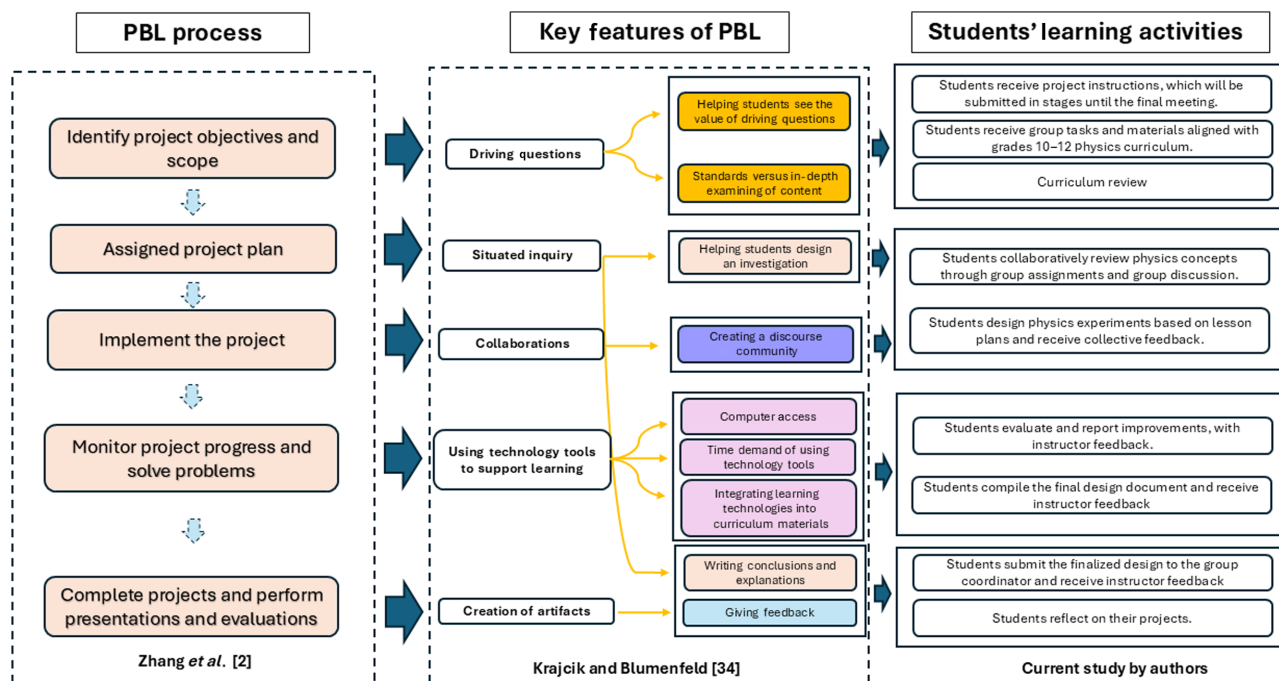


FIG. 1. Examples of students' learning activities in PBL within the designing physics experiments course.

The use of a theoretical framework for the impact of project-based learning on educational outcomes in this study serves as a lens to explore participants' perceptions in interpreting their experiences in PBL. For instance, how participants recall courses they identify as implementing PBL, the nature of their learning environment and approaches, and their perceptions of certain abilities they regard as influential, among other aspects.

B. SCT and Bandura's self-efficacy theory

SCT and self-efficacy theory were both introduced by Albert Bandura. The two theories are interrelated [9]. In a study written by Stajkovic and Luthans [9], they present a framework that connects basic human capabilities in SCT. SCT generally explains the creation of reciprocal relationships between people, environment, and behavior [29]. Meanwhile, self-efficacy in general describes how experience, performance outcomes, vicarious experiences, social persuasion, and physiological feedback interact with each other and form self-efficacy in a person [10].

Stajkovic and Luthans [9] explain that basic human capabilities in SCT include symbolizing, forethought, observation, self-regulation, and self-reflection. Symbolizing describes the ability of humans to visually capture experiences and turn them into cognitive models that are used as a guide to deal with future events. Forethought refers to a person's ability to plan, anticipate consequences, and determine the purpose of the action. Observation explains how one observes people or the surrounding environment to use them as a reference and to reflect on the consequences of each chosen action. Self-regulation explains how a person controls

themselves, sets standards internally, and evaluates the difference between those standards and the performance achieved, with the goal of continuously improving. Finally, self-reflection explains how a person reflects on their actions and determines, through perception, how strongly they believe that they can successfully complete a task in the future.

SCT and Bandura's self-efficacy theory were used in this study as a lens to explore how each participant interpreted their learning experience through the application of PBL. For example, what kind of experience makes them feel confident to be able to do the project assignment given by the teacher, what makes them feel challenged, how they relate to the experience they have had before, and so on. By exploring students' experiences in this manner, the aim is to provide teachers with insights for reflection in future teaching, particularly regarding the decision to implement PBL in online learning. Furthermore, to complement previous research findings related to the implementation of PBL through a qualitative phenomenological approach based on grounded theory [6], in this study, we sought to present a discussion on self-efficacy through interview data, which has been insufficiently explored and which we consider to be the novelty of this research.

III. METHODS

A. Study design

This research uses a qualitative phenomenological approach [37,38] through IPA [27]. Phenomenology is a qualitative approach that aims to find the essence of

an individual's experience regarding a particular phenomenon [39], describes what consciousness feels and knows [40], and reveals the structure of meaning and how it is created [41]. In phenomenological research, phenomena are understood as mental events, events, or cognitive activities experienced by participants [39,42].

A study reported by Cooper [43] guided the authors in gaining detailed information about the complex phenomena of PBL in an online physics class and in identifying themes and theoretical structures that describe this process through IPA. IPA relies on three pillars: phenomenology (phenomenological philosophy), hermeneutics, and idiography [42]. The application of IPA in this study begins with the pillar of phenomenology applied by exploring each participant's response, with a focus on student lived experience based on Martin Heidegger's views [44]. It must be acknowledged by the authors that the interpretation of "lived experience" and the qualitative phenomenological approach still involve ongoing discussion in several writings. For example, Paley [45] refers to his interpretation based on the views of Martin Heidegger, while Giorgi [46] refers to the views of Edmund Husserl, where both phenomenological philosophers are widely known as references in phenomenological research, and both differ in their philosophical understanding of the meaning of human lived experience.

Given that this study does not present the philosophical positions of these two views in depth, we instead refer to Kahija and Smith [27,42], who explain that in Martin Heidegger's view, humans are referred to in German as *Dasein*, intended to convey that humans are "thrown" beings (*geworfen* in German). This means that humans are beings "thrown into the world." As beings thrown into the world, humans give meaning to the various events in their lives, an act that is fundamentally one of interpretation. Based on this framework, the first pillar was applied in this study through the researchers' effort to uncover the interpretation and meaning of students' learning experiences through PBL, as implemented by the instructor and conveyed to the researchers.

The second pillar, hermeneutics, was applied in a way that the researcher provides a way for each participant to interpret his or her experience during the implementation of PBL, and the researcher seeks to interpret the statement of experience conveyed by each participant (double hermeneutic) by applying epoche [47]. Third, the pillar of idiography was applied by considering each participant as a unique individual whose interpretation of their PBL experience is distinctly their own.

B. Participants

This research involved the views of the university's Institutional Review Board as a guarantee of the implementation of research, especially protection for the participants involved in this research. The participants

involved in this study were undergraduate students enrolled in the physics education program. One of the objectives of establishing this program is to produce preservice physics teachers who are considered qualified to teach physics at the senior high school level. In line with this objective, the present study reports findings from a course designed to equip preservice physics teachers with the skills to prepare instructional documents, including lesson plans and physics laboratory experiment designs.

Participant recruitment was conducted after the end of the active course period and was carried out through the WhatsApp application. The first author, who also served as the course instructor, distributed an online form in the WhatsApp groups of students from two different cohorts. Through this recruitment process, a total of 10 students voluntarily agreed to participate in the study. In selecting participants, the researcher adhered to the following criteria: (1) participants must confirm their willingness to voluntarily participate in interviews regarding their past learning experiences and (2) participants must be active physics education students in their fourth or sixth semester who had enrolled in and actively participated in a course taught by the first author using the PBL approach. A total of seven participants from the sixth semester were the primary focus of the study, while additional participants from the fourth semester were included to compare perceptions between the two cohorts at different levels. Based on these criteria, the authors consider that the number of seven main participants in this study is reasonably comparable to the sample size recommended for IPA, which is 3–6 people [27].

For participants who met both criteria, we then sent private messages to them via WhatsApp to schedule interviews. As part of the researchers' obligation to protect all collected participant data, we followed the guidelines established by Lahman *et al.* [48]. Detailed information related to the 10 participants is presented in Table I.

Two classes were selected, the educational planning and curriculum development course and the instructional strategies for physics learning course, consisting of 16 and 21 students. Each class included only two male students, for a total of four male students across both classes. The first author distributed the recruitment form, but none of these four male students completed it. This circumstance represents one of the limitations of the study.

C. Research setting

The present study resulted from pedagogical research [49] in an online physics class of sixth-semester students, observed over four semesters of instruction. The first author observed this class for 2 years, starting from semester III to semester VI. The first author taught five interrelated courses in the class, as presented in Table II.

Table II in the PBL implementation column is the implementation of PBL that is implemented gradually

TABLE I. Demographic conditions of participants.

Participant (pseudonym)	Gender	Semester	Course ^a	Perspective on self-character ^b
Gea	Female	VI	1	Curious
Amy	Female	IV	2	Dreamer
Zahra	Female	VI	1	Introverted
Kanaya	Female	VI	1	Humorous
Fidy	Female	VI	1	Persistent
Ariqa	Female	IV	2	Enthusiastic
Syita	Female	IV	2	Hardworking
Indi	Female	VI	1	Impatient
Lisa	Female	VI	1	Optimistic
Sinta	Female	VI	1	Socially reserved

^a(1) Educational planning and curriculum development and designing physics experiments (taught concurrently to the same sixth-semester cohort) and (2) instructional strategies for physics learning.

^bCharacter categories were self-labeled by participants, reflecting their self-perception.

by the researcher. There are several similarities between the five courses, specifically:

1. All courses were delivered online through Google Classroom, using both synchronous (instructor and students joined the class at the same time) and asynchronous (instructor and students accessed the learning platform independently, at their own time) modes. The agenda for each session was outlined in the first meeting, and each session included learning materials (documents and videos) and student assignments. An example of a course interface is provided in the attachment.

2. The end-of-semester assessment consists of products resulting from the implemented project.
3. Each class is divided into groups based on specific criteria, with one member of each group serving as the coordinator to facilitate coordination with the course instructor.
4. Each student, even though they are in the same group, still has individual assignments, and each student's contribution has a direct impact on the group's assignment.
5. Each student began to compile and work on projects since the week of the PBL meeting. For instance, in the curriculum studies in physics education class, students initiate the end-of-semester project during the 13th meeting and complete it by the 16th meeting.

The difference lies in the level of difficulty of the projects being undertaken. The duration of the work aligns with the complexity of the assigned project. Given the difference in learning settings, we intend to examine the long-term impact of PBL implementation, carried out in stages, on students' ability to optimize the course's output products. Specifically, for courses that are in semester VI, the system is applied in the class as follows:

1. Students started working on the project during the first week of lectures.
2. Details of the topics for each meeting and the mini projects that must be completed each week have been conveyed since the first meeting.
3. The course content relates to the preparation of teaching materials (lesson plans) and the design of physics experiments for senior high school. Classes

TABLE II. List of courses.

Semester	Course name	PBL implementation start from	PBL tasks
III	Curriculum studies in physics education	13th meeting	• Report the results of an interview with a physics teacher • Collect examples of physics teaching materials used in a senior high school • Provide comments on the alignment between the theories discussed in class and the physics teaching materials obtained from the source
IV	Instructional strategies for physics learning	11th meeting	• Produce a video simulation of physics teaching practice by applying a specific instructional strategy
V	Educational assessment in physics	6th meeting	• Develop test instruments for formative and summative assessment. (Each student is assigned physics topics according to the grade level in senior high school)
VI	Educational planning and curriculum development	1st meeting	• Develop a syllabus and lesson plan for senior high school physics instruction, carried out during the initial eight class sessions • Develop a physics learning module for senior high school students, implemented in the subsequent eight class sessions
	Designing physics experiments	1st meeting	• Design physics experiments for senior high school students

Note: Each semester of learning comprises 16 class sessions.

TABLE III. Sample questions on the interview protocol.

No.	Theoretical domain	Question example
1	Process of PBL Exploration of the personal experience of PBL during learning	• According to the perception of your learning experience, what is the character of PBL? • During your time as a student, what experiences did you have while learning with PBL? • What kind of treatment do you think teachers do that can make them better understand the lecture material being taught?
2	Ability in PBL Explore what abilities in students can be influential in the implementation of PBL	• What challenges did you feel during your time in college with PBL? What steps did you take to minimize that challenge?
3	Self-efficacy Seeking meaningful insights into how students view self-efficacy in the learning process	• How do you interpret the conditions of your environment, and how do you perceive your self-efficacy in completing projects during the course? Have any previous experiences influenced your current view of self-efficacy?

are generally divided into three grade levels, corresponding to grades X through XII.

- Each group consists of several students who divide the material content and experimental topics equally according to grade level.
- The product for summative assessment at the end of the semester is the compilation of mini projects completed from start to finish.
- The products generated from two courses are a physics lesson plan document, learning modules, and physics experiment designs for grades X, XI, and XII in senior high school.
- These two courses are offered to students one semester before they begin their school teaching practice, when they hold the status of preservice physics teachers.

D. Semistructured interview

Interviews are considered one of the key sources of information [50] and allow researchers to deeply explore a person's subjective attitudes and personal experiences [51]. This study employed semistructured interviews lasting approximately 50–65 min using a virtual meeting application (Zoom). The first author acted as the primary interviewer during the data collection process. In conducting the interviews, the first author provided an initial explanation and sought participants' permission to record the interview process. Recording began after participants gave their agreement. The files obtained were in the form of an.mp4 file but functioned more as audio files because the interviewer and participants generally agreed to interview with only the microphone activated (without the camera). Out of 10 participants, only two were willing to keep their cameras on throughout the interview.

During the interview process, we referred to the phenomenological approach by interpretative phenomenology [27]. The phenomenon in this study is interpreted as students' awareness of their engagement in learning through the

application of PBL. Based on this definition, the first author sought to explore how each participant uniquely perceives and interprets their experiences during the learning process (PBL), as well as their self-efficacy perceptions. During the interview process, the first author explored the participants' experiences in the courses listed in Table II, as well as in other courses that applied PBL. Table III presents the interview protocol we developed.

E. Data analysis

After the interview data were obtained, the first author transcribed the interview recording file to obtain the interview transcript. In the transcript, the data for each participant were anonymized. The data were then uploaded to a folder that can be accessed jointly by all members of the research team. Then the researchers began IPA of the data [27], which was inductive in nature. In this study, data analysis was carried out primarily using the ATLAS.ti 25 [52]. In addition, other applications, such as Microsoft Excel, were sometimes used as complements, particularly for combining or separating certain themes.

In the data analysis, the researchers were guided by Kahija [42] and Smith [27] following the procedure reported by Cooper [43]. These steps consisted of (1) reading the data repeatedly to become familiar with it (familiarizing the data), (2) making initial notes, (3) developing emergent theme, and (4) creating a superordinate theme. Initial notes made by researchers that included descriptive, linguistic, and conceptual comments [27]. In the initial phase, which involved familiarizing oneself with the data through repeated reading, the researchers immersed themselves in the data to explore information relevant to the research questions. The next step in the process was to create initial notes. This stage was carried out by preparing the interview transcript as a.docx (Microsoft Word) file, presented in the form of a table, allowing the researchers to include exploratory comments. These exploratory comments took the form of the researcher's interpretive

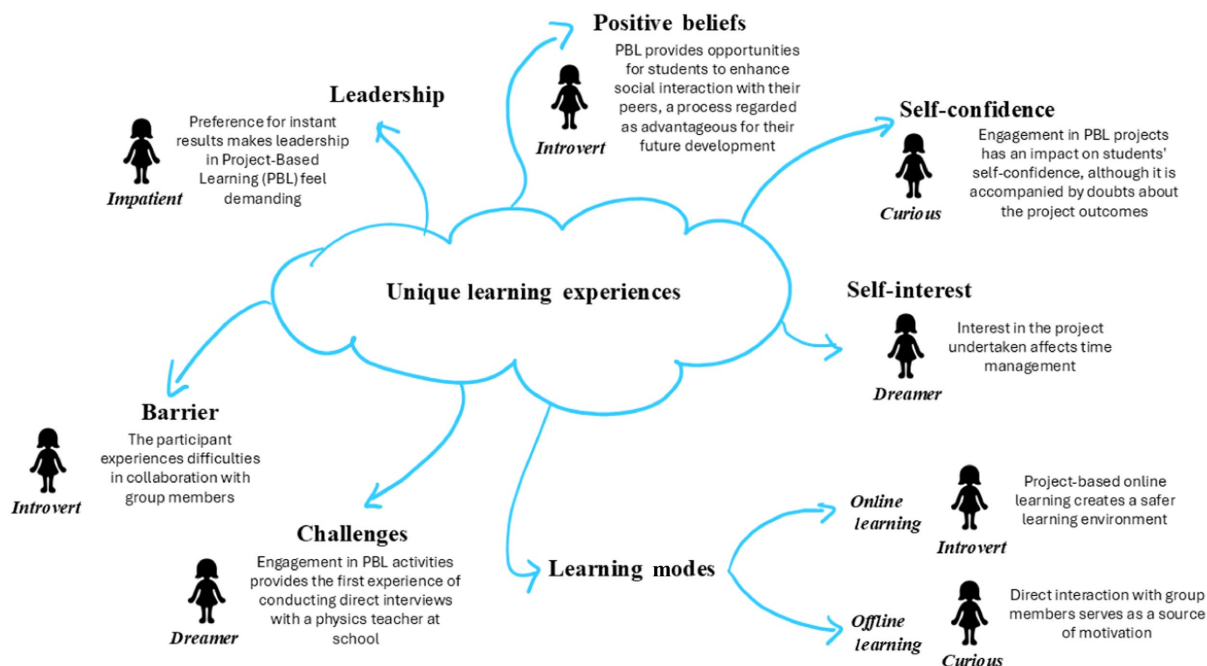


FIG. 2. Examples of learning experiences perceived by participants.

statements regarding part of the participant's statement considered important in the transcript [42].

The third step, creating an emergent theme, was carried out by adding columns to the table in the transcript file to list the theme. These themes emerged through the condensation of exploratory comments made in the previous stage that were seen as interrelated. The themes were not expressed in the form of questions, as in the exploratory comment column, but in the form of phrases or words. The last step was to create superordinate themes, which were formed by merging several emergent themes with similar meanings into a single, larger theme [42].

IV. FINDINGS

The research findings are presented with reference to three theoretical frameworks—social cognitive theory [29], Bandura's self-efficacy theory [10], and the theoretical framework for the impact of project-based learning on educational outcomes [2]—in order to answer the research questions. The findings section is organized around three themes identified during the analysis process: (1) variety of unique learning experiences based on students' perceptions of their own character, (2) pivotal experience as a catalyst in the learning process, and (3) student self-awareness in PBL. The following is a detailed explanation of these themes.

A. Theme 1: Variety of unique learning experiences based on students' perceptions of their own character (RQ1)

Idiography, as one of the pillars of IPA, holds that each participant possesses unique and distinctive characteristics

in making meaning of their experience undergoing PBL. Labeling the character of each participant led to the discovery of various interpretations of experience across multiple aspects. These included leadership, positive beliefs, self-confidence, self-interest, barriers, and challenges in learning, as well as how they perceived their experiences related to the learning mode implemented by the instructor. These aspects are presented as discrete facets of participants' character-based experiences rather than as a sequential or hierarchical progression. Each is discussed independently in the subsections that follow. Examples of participants' experiences based on their character are presented in Fig. 2.

1. Leadership

Participants' experiences related to leadership indicated that serving as a group leader in PBL was generally perceived as demanding while also fostering discipline and encouraging initiative to drive the group. For example, Indi ("impatient") recalled her experience as a leader: "PBL really pushed me out of my comfort zone. I'm the type who wants everything done quickly, so project-based assignments felt tough for me." Nevertheless, in another comment, Indi stated:

As a leader, I felt that PBL really affected discipline, especially when it came to turning in assignments on time. If you want your group members to report their progress and hand in tasks punctually, you must show the example first.

As a comparative dataset, participants from the fourth semester in the instructional strategies for physics learning course worked on projects based on Table II. Each group was given the freedom to independently determine the division of tasks among its members. From this arrangement, one finding emerged from Ariqa (“enthusiastic”), who faced challenges in organizing her group members:

I had to keep coordinating with my friends repeatedly to remind them that we had group assignments to finish, but I didn't get any response. In the end, I only worked with one of my groupmates, so our project was basically the result of just the two of us.

The emergence of this statement prompted the authors to further explore information related to Ariqa's group. In another comment, Ariqa (enthusiastic) revealed: “There was no clear division of tasks within the group.” Ariqa then added:

If I hadn't tried to motivate them (the group members) and taken the initiative to be active in class, the situation would have stayed the same. Only one or two students would have been active in the group.

These findings indicate that the division of tasks among group members in PBL is one of the key determinants of whether group work can proceed efficiently. Furthermore, the challenges experienced by group leaders appeared to foster their awareness of their roles as leaders. Leadership emerged as one of the soft skills that can be developed through PBL, including communication skills.

2. Positive beliefs

The implementation of PBL in this study was generally perceived as a training session for participants to practice several basic skills considered beneficial for the future. These included the ability to collaborate and socialize within the group, perspectives on the learning products produced, and views on the benefits of PBL. Zahra (“introvert”) attempted to describe her condition of finding it difficult to blend into the group through her statement:

I'm the kind of person who easily feels pessimistic, not brave enough to speak up, lacking confidence, and always thinking everything is too difficult to finish. What I remember most from PBL is about collaboration in the group. For me, building teamwork with my classmates had a big impact, especially since I find it hard to socialize and interact with others in class. I only have two or three close friends. So, PBL is really useful in the long run because it trains me to express my opinions to my friends. That skill is

something I will definitely need in the workplace.

Choosing the term *workplace* indicates that Zahra viewed communication skills as a fundamental ability that every individual, including herself, should possess before entering society as a teacher. A related but more forward-looking perspective came from Gea (“curious”), who connected her motivation directly to her upcoming teaching practicum:

I motivated myself and realized that the project tasks in this class (the PBL output) would be needed during the Teaching Assistance program. So, I had to be strong and complete the project tasks.

The Teaching Assistance program is a 4-month school teaching practice that Gea will undertake in the following semester. In a similar spirit of linking coursework to future application, Amy (“dreamer”) stated: “The purpose of creating the product was so that the theories we (students) learned in class could be directly applied.” Ariqa (enthusiastic) and Sinta (“socially reserved”) echoed this theme from their own experience. Ariqa added: “... projects or products that could help students better understand the learning material,” while Sinta reflected: “When I was directly to create the product, I understood more clearly what was called a Lesson Plan, what their functions were, and so on.” These findings indicate that PBL was perceived as a bridge between theory and concrete examples of applying physics learning theory in the classroom. The products generated through project assignments played a role as learning media that could help students understand the subject matter.

3. Self-confidence

PBL challenged the participants' confidence both through project assignments and during classroom learning. This included their belief in their ability to complete the projects. The condition was reflected in two key words: doubt and shyness. For example, Gea (curious) stated:

The tasks in PBL influenced my confidence but at the same time made me feel doubtful about whether the project I worked on was truly in line with the teacher's instructions.

In another comment, Gea explained:

Usually, when we (my group and I) worked on a project and reached the point where it became difficult, we kept asking ourselves whether the task was genuinely hard or whether we were just slow in completing it. In the end, the assignments

we submitted felt like they were only to meet the requirement.

In that condition, the emergence of doubt in Gea's mind indicated that PBL had been able to trigger a situation that provided her with space to evaluate herself and her group, particularly regarding their cognitive abilities and their time management in completing the project assigned by the instructor. Amy (dreamer) recalled her feelings: "When I was assigned the project, I had no clear idea about where to start. I asked myself whether I could do it or not." Meanwhile, Zahra (introvert) described her condition when she found it difficult to understand certain parts of the lecture material but lacked the confidence to raise questions: "... I felt shy when I thought my question might be too simple for the class." The project assignments in PBL appeared to trigger different reactions among the participants, including their confidence in their own abilities.

4. Self-interest

PBL had its own appeal for the participants, particularly in relation to the topics of the project assignments given by the instructor. In this section, the data revealed how interest in the project tasks could trigger the respondents to work on them with optimal effort. An example of a statement representing this aspect came from Gea (curious), who provided a comment.

When designing a learning module, I tried to make the result as optimal as possible. Honestly, sometimes I worked on assignments half-heartedly. But because I preferred the PBL design that required individual creativity, I eventually worked on it patiently, little by little, and I felt that developing the teaching module was the assignment I completed most optimally.

Other findings were obtained through Amy (dreamer), who expressed her interest in developing learning media by commenting:

Because I enjoy working with learning media, I was able to manage my time better when completing the project tasks.

These findings indicated that providing students with space to channel their creativity in project work appeared to function effectively within PBL. The influence of students' interest on their time management in completing projects can be considered by instructors in implementing PBL. This could be done, for example, by involving students in determining the projects to be carried out during the semester. The expectation is that projects agreed upon jointly between instructor and students would be perceived as engaging and meaningful by the students so

that the submitted projects could be completed more optimally.

5. Students' barrier

The barriers experienced by the students originated either from their group members or from themselves. An example of a statement representing this aspect was provided by Zahra (introvert), who gave the following comment:

My experience with PBL was that I found it difficult to work in groups. There were three situations I experienced. First, a condition that felt safe to me, where all group members could join the discussion. Second, only one person was active in the group while the others chose to hand over the responsibility of completing the tasks to the group leader. Third, a group with members who had strong academic abilities. However, the project could not be completed on time because it was difficult for the members to reach agreement, as each had different opinions and preferences.

Beyond the interpersonal barriers described by Zahra, some participants pointed to self-directed barriers instead. Gea (curious), for example, attributed her shortcomings to personal time management rather than group dynamics: "Actually, the project could have been done more optimally, but I was not able to manage my time well." Amy (dreamer) reported a closely related struggle:

For the project tasks, I very often produced results that were not optimal because of my poor time management. I frequently postponed the work and spent too much time, especially scrolling on social media.

These findings showed that PBL appeared to encourage Zahra to identify the characteristics of the groups she had worked with. This condition was considered essential, particularly for Zahra as a preservice physics teacher. Such experiences can serve as a reference when she teaches physics and selects learning strategies that involve group division. At the same time, the findings provided important information for instructors in implementing PBL, highlighting the need to pay attention to the structure of group membership. In addition, PBL encouraged the participants to engage in self-evaluation, particularly in terms of time management.

6. Challenges

Through the implementation of PBL, the participants generally experienced challenges in completing the project tasks assigned by the instructor. An example of a statement

representing this aspect came from Amy (dreamer), who described her condition when she was first given the task of interviewing a physics teacher at school:

It was an experience that made me feel challenged because, in the Physics Curriculum Review course [Curriculum Studies in Physics Education course], we were asked to conduct observations at school. That was the first time I had ever interviewed a teacher.

Amy, in another statement, added a comment:

The teacher was already experienced in teaching Physics. Indirectly, the information she shared was important for us as preservice teachers in the future.

The findings showed that PBL provided students with opportunities to encounter new experiences they had never gone through before, including enriching their learning as preservice physics teachers.

7. Learning modes

In this study, the authors explored the participants' experiences in both offline and online learning, as well as their perceptions of conventional learning and PBL, based on their individual characteristics. The sixth-semester students had experienced their first year of study in an offline setting, while in the second year up to the sixth semester, the courses were conducted online. Meanwhile, the fourth-semester students had undertaken their first year of study entirely online from the beginning of their academic program.

Offline learning and online learning. The experiences felt by the participants in relation to offline and online learning were confirmed in diverse ways. In general, they included adaptation, personal character alignment, challenges encountered, and a sense of responsibility. An example of a statement representing this aspect came from Lisa ("optimistic"), who described her experience when she was assigned a project to interview a physics teacher:

At that time, I had not yet thought of the idea of conducting the interview virtually because it was still the period of adjusting myself to online learning.

PBL conducted online required Lisa to adapt, including learning to use new applications that had not been relevant in offline learning. Subsequently, Gea (curious) gave a comment:

For offline learning, I felt more enthusiastic about working on the project, especially when

it was a group project. My groupmates and I could encourage each other. In addition, the project results also became visible more quickly in terms of progress.

For Gea, working on projects through offline learning was more suitable for her, as it provided benefits that could be directly experienced. In contrast, Zahra (introvert) felt safer learning from behind the screen, as reflected in her statement: "I prefer online learning because of my character, which makes me feel more comfortable in a safe learning environment." However, in another statement, Zahra provided a comment related to the challenges she experienced in online learning:

For online learning, I considered the challenges to be greater. First, there was the problem of internet connection. Second, it was difficult to communicate online with group members, especially when trying to decide on a time for discussion. Group members often struggled to be present on time for various reasons, so the discussion could not take place.

Meanwhile, Gea (curious) stated: "For online learning, since we worked individually, the tendency to feel lazy was also stronger." As for Syita ("hardworking"), she described her experience in line with Zahra:

During the project work in online courses, the challenge was the internet connection. In addition, I also faced difficulties in finding information while working on assignments because sometimes the information from the internet was so hard to understand.

Findings on students' sense of responsibility in both learning modes were illustrated by Zahra's comment: "For me, it is the same (online and offline learning)." The interpretation of learning experiences in offline and online modes with PBL in the context of this study implies, among other things, the need for instructors to pay attention to students' individual characteristics in order to provide appropriate choices of learning modes. In addition, online learning indicated the importance of classroom discussions between instructor and students to evaluate students' understanding based on information obtained independently, as well as to monitor the progress of each group discussion.

PBL and conventional learning. The participants' perceptions of their experiences between conventional learning and PBL were illustrated, for example, through Amy (dreamer), when she was asked how she interpreted her experience of being assigned to directly interview a physics teacher in a PBL mini project compared to the

conventional learning she had commonly experienced before. Amy stated: “It was very different between conventional learning and PBL. For example, in terms of interview skills.”

The delivery of material in conventional learning was generally teacher-centered and focused only on theoretical aspects of the course. In contrast, the implementation of PBL, as a student-centered approach, provided opportunities for students to directly observe examples, as experienced by Amy. Her interview with a physics teacher offered a memorable experience, as reflected in her statement: “... since that is rarely done, it would probably feel more memorable.” Through this interview activity, Amy felt that her interview skills had improved compared to before. It was evident that the two learning strategies were perceived with different impressions by the participants.

Taken together, the seven facets discussed above, namely, leadership, positive beliefs, self-confidence, self-interest, barriers, challenges, and learning modes, illustrate that participants’ character shaped not only how they experienced PBL but also which aspects of the process they found most salient. These individual variations set the stage for examining how the instructor’s classroom design responded to this diversity of character. Therefore, the following section turns to the collective learning processes and classroom mechanisms, such as memorable rules, monitoring practices, and instructor feedback, that catalyzed these experiences across the cohort.

B. Theme 2: Pivotal experience as a catalyst in the learning process (RQ2)

In this section, the authors explore the participants’ perceptions related to PBL. This exploration includes how they interpret PBL, which rules are particularly memorable for each participant in undergoing PBL, and how they uncover strategies for learning. In addition, the authors observed participant testimonials and identified variables that may have influenced their experiences with PBL.

1. Students’ conceptions of PBL

The description of how each participant interpreted PBL generally revealed that PBL was characterized in the form of keywords. In addition, some participants chose to answer this question by connecting their theoretical knowledge of PBL with their direct experiences in courses that required them to complete projects or products. An example of a statement representing this aspect came from Gea (curious), who stated: “The keyword that came to my mind when discussing PBL was progress.” In another comment, Gea expressed:

... in PBL students are asked to work on a project within a certain period of time and are trained to consistently make progress at each stage.

Another finding was obtained through Zahra’s comment as an introvert:

In the Educational Planning and Curriculum Development course, all six stages of PBL were present. However, I once wondered whether the previous semester’s course could be considered PBL even though the outcome was a project. There were some stages of learning that, in my view, were not implemented.

Gea’s statement indicated that PBL was able to provide a learning experience with distinctive characteristics, specifically “project” and “progress.” In contrast, Zahra’s statement demonstrated that PBL offered opportunities for students to experience learning directly through the application of various student-centered approaches. Furthermore, the stage in which Zahra reflected by analyzing the phases of PBL both theoretically and through her learning experience showed that her cognitive knowledge had reached the level of metacognition. For the authors, this finding will be beneficial for students, particularly as preservice physics teachers.

2. Memorable rules of PBL

The data obtained by the researchers indicated findings related to several classroom rules that were memorable for the students, including how the participants discovered ways to learn. These included (1) semester timetable, (2) the preferred PBL design, (3) monitoring of project progress, and (4) collection of lecture materials.

Semester timetable. One of the rules applied in the PBL class implemented by the authors was the requirement to submit a mini project every week according to the semester schedule. This rule was generally perceived as either positive or negative. An example of a statement representing this aspect was from Gea (curious), who explained: “The method required us to show progress every week. We were pushed to study harder, and eventually I could understand the material.” Another comment came from Zahra (introvert), who expressed: “It was not a problem to report progress every week. In fact, it made me better I used to postpone assignments, but this rule encouraged me to work on tasks earlier.”

Another comment was provided by Fidy (“persistent”), who stated:

In Google Classroom, the deadlines for each assignment were clearly outlined, and the materials being discussed or already covered were also listed. I was able to review the lecture materials again, and for me, this made me more disciplined.

Subsequently, Lisa (optimistic) added her perspective:

I was taught how to manage my time, how to create a good schedule, and how to set final targets to be achieved. But, when other courses also required certain assignments to be completed, the overlapping deadlines often made me complain. However, I eventually thought that although the tasks might be numerous, compared to the positive side of training me to manage my time well, I tried to achieve my learning targets.

These findings indicate that PBL, with the setting of weekly progress reporting for assignments, appeared to encourage students to study more diligently and played a role in training them to manage their time in completing and submitting tasks. Although certain participants felt that the process was demanding, it seemed to be believed that such an approach would ultimately have a positive impact on them.

Preferred PBL design. The students who participated as respondents in this study confirmed that they had experienced several classes implementing PBL. Some of their statements indicated that the participants had particular attention to the design of PBL that they preferred. This included the assignments given, the way the instructor presented the learning materials in class, and the manner in which the instructor evaluated the learning strategies applied.

An example of a comment representing this aspect was from Gea (curious), who stated: "I prefer a PBL design that requires students to complete assignments demanding their own creativity." This statement appeared to align with the comment from Fidy (persistent), who expressed: "I was glad because in PBL I was trained to think creatively in order to generate ideas." Although project assignments were generally divided into groups consisting of four to five students, the PBL setting implemented in the class still required each group to provide feedback to the instructor regarding the clarity of task distribution among group members based on mutual agreement. The presence of this rule positioned PBL as a learning approach that offered students space to create in completing project tasks according to their personal interests without intervention from their peers. Thus, through these findings, the participants indirectly confirmed that completing project assignments involved processes of critical thinking and creative thinking.

Another finding emerged through a comment provided by Fidy (persistent), who stated:

I feel that the instructor respects our comfort as students in the classroom. It is rare for an instructor to ask us about the kind of learning we prefer. For me, that is important because it

increases my motivation to learn. The level of comfort and the learning conditions of the students are highly decisive for the quality of the learning process.

Fidy's statement indicates that it is considered important for students to be involved in providing their perspectives on the learning strategies implemented for them. In this study, one of the approaches to evaluating PBL was conducted by asking students to provide feedback periodically regarding the PBL setting applied in the classroom. This section enabled the instructor to explore students' views more deeply, such as asking how they experienced the process of completing the project, whether the project helped them to better understand the material being taught, and requesting students to connect the examples of project implementation with the needs of a physics teacher in actual school teaching practice, among others. Evaluating learning and identifying students' needs based directly on their perspectives will be beneficial for instructors in designing subsequent learning strategies.

Monitoring of project progress. Monitoring of project progress became one of the rules that was memorable for the students. The confirmation of experiences conveyed by the participants was interpreted in diverse ways, both positive and negative. Task monitoring was conducted weekly through synchronous and asynchronous modes (see Research Setting section). The synchronous mode was carried out through discussions with students, in which the instructor provided comments on one of the students' assignments during a lecture session via the Zoom meeting application. Meanwhile, the asynchronous mode was conducted by the instructor providing video comments on the results of assignment reviews in Google Classroom, which students could watch at their own convenient time.

An example of a comment related to this aspect was given by Gea (curious), who stated:

Several times the instructor gave comments on my assignment. At other times, the instructor gave comments on my peer's assignment. I paid attention to the shortcomings in my peer's work, and I realized that the same shortcomings were also present in my own assignment. That helped me evaluate my work.

Zahra (introvert) expressed a similar appreciation for this stage: "I liked that stage of task monitoring because it helped me see whether what I understood and how I did the assignment was actually right or still wrong." Task monitoring in PBL provided students with the opportunity to independently correct their work, either through the instructor's direct comments on their own assignments or through comments given on their classmates' work. Indi (impatient) highlighted a further benefit, specifically its

role in discouraging plagiarism: “It is unlikely for plagiarism to occur because the progress of project assignments is checked one by one by the instructor.” The clear division of tasks for each student within the group, combined with systematic monitoring of assignments, has so far shown that PBL with these settings fosters students’ creativity in completing their work while at the same time preventing them from producing assignments with identical content.

Receiving suggestions and feedback from others does not always occur under the right conditions. Many factors may influence this process. In the data obtained, there were findings indicating that task monitoring was not always perceived as a positive experience. Sinta (socially reserved) shared an experience that differed from the other participants:

It was my first time submitting a product and also the first time my work was commented. At that moment, I wanted the instructor to focus on pointing out which parts of my work were wrong. But that day I felt put on the spot, and I felt embarrassed in front of my classmates.

These data indicate that monitoring the progress of project assignments requires special attention from the instructor in PBL. Paying attention to students’ psychological conditions before and during the provision of comments, as well as being mindful of the choice of words used by the instructor, becomes one of the keys to the success of this stage. A comment from Sinta (socially reserved) suggests that although the information about the shortcomings in her product was clearly conveyed by the lecturer, there were certain expressions that made her feel singled out. The psychological condition of a student in undergoing the learning process will influence their performance in learning.

Collection of lecture materials. Implementing PBL through the Google Classroom platform in the context of this study, the instructor provided learning materials in the form of reading files in.pdf format and videos in.mp4 format or online links such as the instructor’s YouTube channel. In general, this was positively received by all participants. For example, Zahra (introvert) stated: “I like online learning with videos because I can replay them. I need to replay it several times.” In another comment, Kanaya (“humorous”) stated: “When I missed some parts of the material, I could replay the video and use it as a guide for my next assignment.” One of the advantages of implementing PBL in online classes is that it allows instructors to provide learning materials that students can access at any time. The use of online learning platforms is not limited to the period when students are enrolled in the course during the semester but can also be utilized even after they have completed the class. These resources remain useful for future access when preservice

physics teachers enter the school environment and begin teaching physics in the classroom. A synthesis of the findings above is provided in Table IV.

3. Student variables enhanced through PBL

From the data analyzed, several findings on the implementation of online PBL indicate the potential for enhancing abilities beyond those previously mentioned in earlier themes (such as leadership, social skills, and group collaboration). Participants’ statements generally show that completing project assignments in PBL requires complex competencies, fostering adaptability, problem-solving skills, and building resilience.

An example of comments representing this condition can be seen from Fidy (persistent), who stated: “*Many skills are involved, such as improving technological skills when searching for references or when working on the project.*” Another finding is reflected in Gea (curious), who recalled her experience of feeling bored while working on the project through the following statement:

When I was alone and felt lazy to work on the project, I went to my friend’s house so we could motivate each other. Sometimes I chose to take a short walk instead. I tried to find ways to get my mood back. After that, I could continue working on the project again.

The following statement comes from Kanaya (humorous), who described her condition when she lost her assignment file 2 days before the submission deadline. She commented:

That night I cried and let out my emotions. But the next day I tried to redo the whole project from the beginning, working on it for two nights. In the end, I finished the assignment before the deadline. I thought I wouldn’t be able to get through it, but it turned out I could.

The implementation of PBL requires students to consistently work on projects throughout an entire semester. Therefore, it is reasonable that one of the participants described PBL with “consistency” and progress. Experiencing challenges during the course process is something natural for students. However, how students can respond, persist, and strive until they finally overcome those challenges becomes one of the meaningful findings in this study. This is reflected in the statements given by Gea and Kanaya.

4. Others testimony

One of the long-term goals of developing instructional products in PBL classes, as reported in this study, is to prepare students before entering their teaching practicum in

TABLE IV. Memorable rules of PBL.

Rules of class	Findings from students' perception
Semester timetable: • Implementation of a time schedule for one semester • Collect tasks at regular intervals	Positive: Students felt: • Encouraged to study more diligently • Trained to manage time well Negative: • Students occasionally express complaints when multiple assignment deadlines coincide within the same period
Preferred PBL design: • Clear division of tasks within each group • Instructional delivery with concrete product examples • Evaluation of PBL strategy by asking for student feedback periodically	Students felt: • They were given space to develop their own creativity • Can improve other skills such as using various applications to prepare physics teaching media and materials and searching for references • Easy to understand the learning material • Appreciated and experienced an increase in learning motivation
Monitoring of project progress: • The instructor randomly selects student submissions and provides feedback on the collected project assignments	Positive: • Students could correct their work independently • Students perceived that monitoring assignments reduces the likelihood of plagiarism among students Negative: • Students are perceived as being placed in a vulnerable position when their work receives critical comments from the instructor
Collection of lecture materials • The instructor provided learning materials on Google Classroom in .pdf and .mp4 formats	• Students felt facilitated to reaccess learning resources provided by the instructor for learning needs

schools. Through interviews conducted with the participants, several statements were obtained that describe their experiences during this period. In general, the responses illustrate how the products developed during campus-based learning could be meaningfully applied in real school settings. Several examples of comments representing this section include the statement from Indi (impatient):

Yesterday we (students) created a teaching module as a product from the course at the university. It turned out that no teaching module was available at the school. Therefore, it felt as if we were bringing something new to the school. I used the teaching module and the practicum module at the school. That was very helpful.

Another comment came from Fidy (persistent), who stated:

I was assigned to teach Grade XII, and I used the student worksheet (LKPD) in class. I applied the course product at school, and I was really happy because the material I created could actually be used there.

One of the advantages offered by PBL is that it provides students with the opportunity to work on projects that

reflect real-world needs. Through the implementation of PBL in an online class, preservice physics teachers engaged in a series of learning activities and demonstrated that they could experience the direct benefits of PBL. Based on the findings obtained, the author argues that PBL deserves consideration as a learning strategy, particularly in preparing preservice physics teachers to be trained as professional educators.

Overall, the classroom mechanisms examined in this section, namely, semester timetables, preferred PBL design, progress monitoring, and material accessibility, functioned as catalytic structures that translated participants' individual characteristics (theme 1) into concrete learning behaviors and skill development. Beyond these classroom mechanisms and collective experiences, participants' engagement with PBL also prompted a more introspective process. The following section examines how these cumulative experiences were internalized through participants' self-assessment and reflection, specifically in relation to their self-efficacy.

C. Theme 3: Student self-awareness (RQ3)

This section presents participants' statements related to student self-awareness, which include aspects of self-efficacy and self-reflection during PBL. In line with this, the discussion is organized into two emergent themes:

TABLE V. Students' self-rating of their self-efficacy.

Participant name(pseudonym)	Perspective on self-character	Self-rating	Comments
Gea	Curious	3	"I feel I could still do better, but I haven't reached that point yet"
Amy	Dreamer	3	"Sometimes my self-efficacy feels high, but my actions don't always match it"
Zahra	Introverted	2.5	"At present, I am still far from having strong self-efficacy because I remain quite pessimistic"
Kanaya	Humorous	3	"I still have a bit of doubt"
Fidy	Persistent	4	"Through PBL, I learned many new things, and it really boosted my confidence"
Ariqa	Enthusiastic	3	"Compared to high school, I've grown a lot in college. But I didn't choose a rating of 4 because I still feel there's much, I want to improve"
Syita	Hardworking	3	"Sometimes I feel incapable, but then I remind myself that I have to be able to do it"
Indi	Impatient	3	"At the very least, my understanding of the course material is much better than before"
Lisa	Optimistic	4	"I've started to understand myself and realized that I can complete my coursework well"
Sinta	Socially reserved	2	"I still have a lot to learn"

students' self-rating of self-efficacy and students' self-reflection based on prior experiences.

1. Students' self-rating of self-efficacy

The general findings on students' self-rating of their self-efficacy are presented in Table V. During the interview process, participants were asked to select a scale from 1 to 4 to rate their self-efficacy.

Referring to the self-rating column and participants' comments presented in Table V, it is evident that the scale positions carry different meanings for each participant. For instance, those who selected scale 3 (the most frequently chosen option)—such as Gea, Indi, and Ariqa—did so because they felt there were aspects of their work that could still be improved beyond what they had accomplished so far. In contrast, Amy, Syita, and Kanaya confirmed their choice of scale 3 as being appropriate to their position, often due to feelings of doubt or self-barriers. Within this context, qualitative research plays an important role in exploring these nuances beyond what can be captured through quantitative data.

In addition, there is a possibility of differences in the basic benchmarks used by participants when selecting their scale ratings. For example, Zahra (introvert) expressed in her comment:

Before I took this class, I thought my self-efficacy was at zero. For me, reaching 2.5 is already quite a big improvement. I've become more confident in expressing my opinions, and I see that as a positive impact on my self-efficacy, which was quite low before.

Zahra's comment shows that she considered her starting point to be zero, and after experiencing PBL, her self-efficacy increased to 2.5. This interpretation may not apply to other participants, and therefore it can be explored further in future research and is considered a limitation of this study. For participants who selected scale 2 or below 3, specifically Zahra and Sinta, both viewed themselves as students who face challenges in socializing with classmates. In contrast, participants who chose scale 4 were those who perceived themselves as having made significant progress during the course and regarded their achievement as the optimal effort they could accomplish.

2. Self-reflection based on prior experiences

In this section, the authors present participants' statements related to reflection based on past experiences, including those gained through the implementation of PBL. The general findings are presented in Fig. 3.

The discussion on students' perceptions of self-efficacy in undergoing PBL can be illustrated through their appreciation of personal achievements, awareness of their developing abilities, and recognition of the importance of believing in their own capacity. Gea (curious), Zahra (introvert), and Lisa (optimistic) commented,

I realized that I could reach this stage, and perhaps in the future I can try a little harder than now so that the results will be more optimal.

Previously I had difficulty coordinating with my classmates, but the courage appeared spontaneously because it was already the deadline.

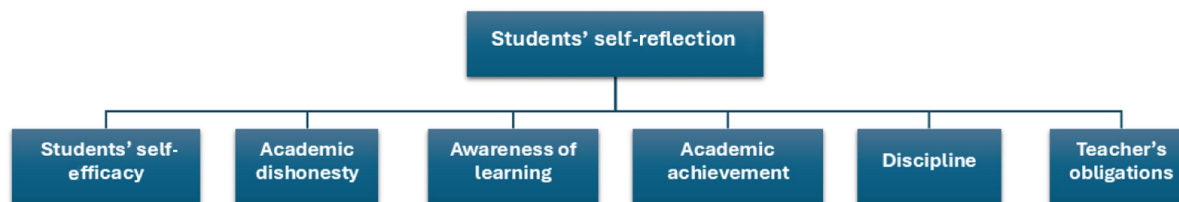


FIG. 3. Examples of students' self-reflection on prior experiences.

I have learned many new experiences, I am beginning to have confidence and the ability to compete positively with my classmates, I study more than I did before.

PBL appears to have stimulated participants to reflect more deeply beyond simply attending lectures, including planning for the future by recognizing their current abilities. Furthermore, Indi (impatient) described one of her experiences when she worked hastily and realized something from that incident through her comment:

I just wanted to finish the assignment without much effort, so I copied my friend's work, and that left me not understanding the material. Later I realized that doing the assignment on my own makes it easier to understand the material clearly.

In another statement, Indi (impatient) expressed, "All knowledge is useful, there is no such thing as learning something in vain." This additional comment, when connected to her previous reflection, indicates that copying assignments did not make her better, and through that experience she discovered how she should learn and how she views the meaning of learning itself. Eventually, Indi (impatient) reached the stage of reflection in which she interpreted the academic achievement she obtained. This was evident in her third comment, where she stated:

I realized that in this class (PBL), besides learning the material, the activities also shaped my character to be more mature without me noticing. Before, I only focused on grades as the measure of success. Now I see things more openly, especially the connection between the effort I put into assignments and the results I get, as well as how others value the effort I make.

Another comment came from Kanaya (humorous), who stated:

Honestly, when I joined the class activities, I felt a bit burdened, but it turned out to be good for me. I felt I became more disciplined. At first, I wasn't sure, but over time I started to feel confident.

A similar statement was also found in the comment of Fidy (persistent), who said: "... and for me, that made me more disciplined." These findings indicate that PBL encourages the development of discipline as a character trait among students. If the previous four comments reflected the point of view from the students' side, Syita (hardworking) shared her learning experience by stating: "... even though it was only in front of my classmates, I could feel that being a teacher is actually difficult." In a teaching simulation, Syita realized that becoming a teacher is not an easy task.

These findings demonstrate that PBL, as a pedagogical strategy, progressively fosters students' awareness through reflective engagement across structured learning activities. This reflective process not only strengthens their identity as learners in the classroom but also shapes their emerging role as preservice physics teachers. The cumulative experiences derived from PBL have the potential to yield enduring educational outcomes, underscoring its capacity to integrate cognitive development with professional identity formation.

D. Summary of results: Learning by doing

Based on the findings outlined above, several keywords can be identified that represent the results of the analysis of participants' perceptions of their learning experiences and self-efficacy throughout the PBL process. The character labels assigned by each participant to themselves reflect the unique ways in which they made meaning of their learning experiences, encompassing not only cognitive aspects but also noncognitive dimensions. Although participants acknowledged that the PBL process presented considerable challenges, they believed this experience would be beneficial for their future.

During the early stages of PBL implementation, participants generally experienced doubt regarding their ability to complete the project, compounded by technical constraints in the online learning mode (such as limited internet connectivity) that hindered group coordination. Subsequently, several catalytic factors emerged that optimized the learning process, including participants' interest in the project content and the PBL design implemented by the instructor, particularly periodic task monitoring and student involvement in evaluating the learning process.

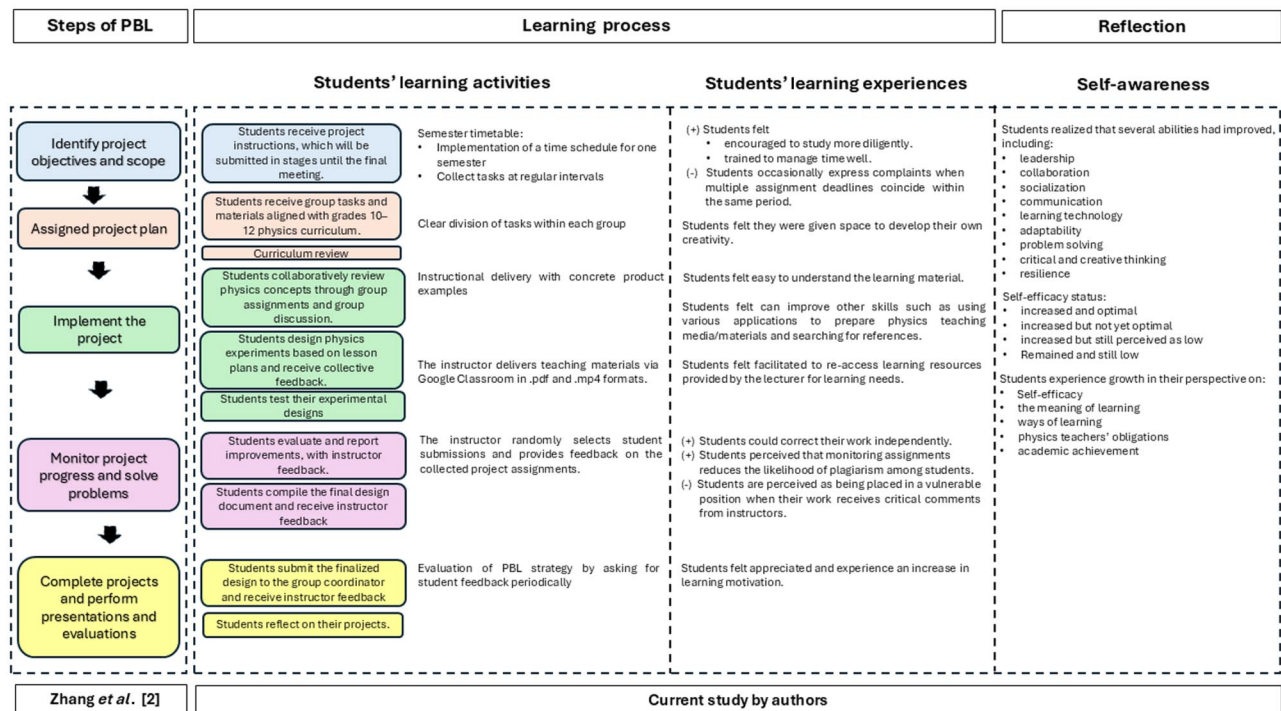


FIG. 4. Summary of the findings.

Periodic monitoring served as a means for independent evaluation of completed project tasks, continuous improvement, and contextual examples that allowed course material to be not only understood theoretically but also applied directly in practice. Beyond serving as a means of progress reporting, periodic monitoring was also understood by participants as a form of character development, specifically cultivating discipline and fostering a more mature perspective through reflection. Confidence that was initially uncertain grew gradually, even though participants recognized there remained room for further optimization. Overall, they underwent a process of learning by doing, evident in group interaction, the transition from offline to online learning, and project execution. Ultimately, this learning experience brought students to a broader instance of learning by doing, learning to transition from students to physics teachers. This experience fostered self-efficacy and a more developed perspective than before. A summary of the findings of this study is generally presented in Fig. 4.

V. DISCUSSION

A. RQ1: What is the student's perception of themselves and their learning experience in project-based learning?

The assignment of character labels to each participant was intended to represent how they perceive themselves in relation to SCT [29]. This is connected to the concept of self-regulation, which describes the condition in which

individuals can control themselves, establish internal standards, and evaluate discrepancies between those standards and their actual performance [9]. In relation to Bandura's self-efficacy theory, this corresponds to performance outcomes, which emphasize the relationship between ability and effort, serving as a reference point for individuals based on past experiences [29].

The character labels confirmed by each participant revealed diversity among the 10 participants. Although these data are not discussed further in this study, the findings provide insights into the selection of learning modes and group interaction patterns according to individual characteristics. Teachers' understanding of students' character mapping enables more comprehensive instructional planning to address diverse learning needs and to foster a sustainable learning environment. Within the implementation of PBL, instructors are required to develop assessment processes, plan activities, and determine the types of learning products expected [6].

The differences in character reflect the uniqueness of each individual in interpreting their learning experiences (Fig. 2). These findings are consistent with previous studies, which reported that PBL enhances group collaboration skills [1,15,18], fosters students' self-confidence [6,15,22], and reveals student barriers arising from both internal and external factors [15,20], as well as other competencies [9]. A novel insight from this study is that PBL also cultivates leadership skills among group leaders and naturally develops resilience throughout the learning process, aligning with the theory that self-efficacy is a

strong predictor of other performance outcomes, including resilience [10,22].

Another essential finding is that, although participants experienced discomfort during PBL, such conditions were still perceived as positive and beneficial for their future. This complements previous research reporting that students' attitude scores toward PBL were lower compared to scores for learning, critical thinking, and student engagement [18]. This underscores that, despite moderate attitudes toward PBL, students continue to believe in the long-term benefits of the learning experience.

B. RQ2: How is the project-based learning design that students are interested in and how do students feel the benefits of the projects they are working on?

The findings regarding memorable and student-preferred classroom rules in PBL are elaborated in Sec. IV, Table IV, as one of the novel contributions complementing previous studies. Consistent with earlier findings, PBL cannot be implemented efficiently without adaptation to students [53] and requires teachers' readiness to design comprehensive instructional plans, both technically and in terms of content [5].

With respect to PBL as a learning strategy oriented toward real-world connections, prior research has shown that PBL in physics facilitates conceptual understanding through everyday phenomena [6,20] and deeper comprehension of core physics concepts [19], though limited to conceptual improvement. This study introduces new findings in the form of active engagement of preservice physics teachers in producing authentic instructional documents such as lesson plans, laboratory experiment designs, and formative and summative assessments, which represent practical needs of teachers in the field. Student involvement in developing these documents through PBL was found to elicit positive responses.

Another novel insight is that PBL fosters metacognition among preservice physics teachers, defined as the condition of reflecting on their own cognitive processes [54]. In this study, metacognition was evident primarily through reflective experiences after learning, for instance, when students critically examined the alignment between theoretical stages of PBL and its implementation while role-playing as learners. Additional findings relate to teacher treatment, such as semester timetables and student involvement in evaluating the learning process. These findings have implications for PBL implementation across diverse classroom contexts, particularly online modes, given the accessibility of open reading materials and instructional videos that support independent learning. This aligns with students' preferences for learning through videos, demonstrations, and experiments [6]. Zhang and Ma [2] reported that PBL is more effective in laboratory classes than in theoretical ones; however, the present study

demonstrates that PBL can also function effectively in theoretical classes.

The benefits perceived by students are consistent with prior studies, such as improvements in problem-solving and creative thinking [2,17], as well as the ability to develop multimedia teaching materials, deliver effective presentations, and acquire teaching skills [6]. A new contribution of this study lies in the experiences of preservice physics teachers following PBL and teaching practice in schools: course outputs were regarded as tangible evidence of their competencies, proven to be applicable in school physics instruction, and valued as meaningful learning outcomes. These findings are consistent with the view that PBL promotes meaningful learning [6] and that projects relevant to community needs enhance students' academic engagement [20].

C. RQ3: How do students perceive their self-efficacy based on their experience in project-based learning?

How does PBL give meaning to each participant's reflection at the end of learning?

Findings regarding the assessment of self-efficacy through self-rating indicate that the choice of scale does not guarantee a shared meaning among participants in their comments. Pedagogical research conducted over four semesters (sixth-semester students) and two semesters (fourth-semester students) through the implementation of PBL shows that PBL does not automatically influence self-efficacy. Consistent with findings that among the four affective attitudes (motivation, attitude, learning interest, and self-efficacy), PBL exerts the weakest effect on self-efficacy [2], and successful experiences do not necessarily generate strong general expectations of efficacy [10]. The 10 participants were categorized into four statuses: (1) increased and optimal, (2) increased but not yet optimal, (3) increased but still perceived as low, and (4) remained and still low. The self-rating data revealed that most participants fell into the second status.

Previous studies have reported that PBL enhances students' self-efficacy [6,14,23], including significant improvements among female students [22]. The novel contribution of this study is that the qualitative approach not only mapped self-efficacy based on participants' confirmations but also revealed how character tendencies shaped the meaning of self-efficacy, including reasons for scale selection and the experiences underlying them. For example, two participants who selected scales below 3 both reported difficulties in group collaboration; however, one confirmed being in status 3, while the other was in status 4, underscoring the importance of qualitative approaches in capturing individual experiences in depth. This finding complements prior quantitative studies that inferred self-efficacy solely from average scores [14,23], as well as qualitative studies that reported self-efficacy through interviews without deeper discussion [6].

Self-reflection following a series of PBL activities demonstrated that students developed new perspectives on self-efficacy, the meaning of learning, learning strategies, responsibilities as future physics teachers, and academic achievement. These findings align with self-efficacy theory [10] and social cognitive theory [29], encompassing aspects of performance outcomes, vicarious experiences, and physiological feedback in self-efficacy theory, as well as observational learning, self-regulation, and self-reflection in SCT. The competencies developed during PBL are also consistent with the findings of Zhang and Ma [2].

This study has several limitations. Three directions merit particular attention in future research. First, given the gender homogeneity of the present sample, future studies could deliberately design recruitment strategies to include male preservice physics teachers, allowing for a more direct examination of whether gender shapes the experience of self-efficacy within PBL, complementing earlier quantitative evidence on gender gaps in self-efficacy [22]. Second, the finding that identical self-rating scores carried different meanings across participants, depending on each individual's implicit baseline, suggests that future work would benefit from pairing IPA-based interviews with a validated self-efficacy instrument administered both before and after PBL implementation, enabling clearer interpretation of change against an explicit baseline. Third, longitudinal research tracking preservice physics teachers from PBL coursework into their initial years of classroom teaching would provide stronger evidence of the long-term contribution of PBL to professional readiness, extending beyond the retrospective testimonies reported by a subset of participants in this study.

VI. CONCLUSION

The distinct character interpretations assigned by each participant reflect the unique ways in which they made meaning of their learning experiences. Several factors contributed to participants' interest in actively engaging in learning and to the benefits they derived from this engagement. Although PBL was implemented in this pedagogical research, the data indicate that PBL did not consistently

exert a significant effect on how each participant construed self-efficacy. Rather, prior experience appeared to play a more substantial role in shaping the way participants perceived their own self-assessment. Through self-reflection, participants ultimately made meaning of their experiences throughout the PBL process and demonstrated a growing perspective across various aspects, particularly in their role as prospective physics teachers.

Beyond enhancing understanding of course material, the implementation of PBL also improved participants' abilities in both cognitive and noncognitive aspects. These findings suggest that PBL can be considered a strategy for introducing prospective physics teachers to the process of preparing for classroom instruction prior to actual teaching practice. The implementation and evaluation of PBL applied by the instructor in this study are considered adaptable to other classes with similar contexts, thereby offering meaningful contributions to teachers, particularly physics teachers, in selecting PBL as an instructional strategy. These findings are supported not only by quantitative evidence from previous studies but are further reinforced by the qualitative findings discussed in this paper.

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