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Effectiveness of Problem-Based and Project-Based Learning Models in Achieving Competencies in Database Learning

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Abstract

This research aims to develop a Problem-Based and Project-Based Learning model to help students who struggle to achieve database learning competencies. This development research refers to the Research and Development method. The model's syntax consists of three stages-introductory, core, and concluding activities-implemented in six learning phases. A quasi-experimental design was conducted involving 30 students in the treatment and control groups. Statistical analysis showed that the Problem-Based and Project-Based Learning model significantly improved learning outcomes across cognitive (80.90 vs 65.93), affective (125.28 vs 85.13), and psychomotor (123.83 vs 95.40) domains, with a significance level of 95%. These findings highlight the effectiveness of Problem-Based and Project-Based Learning in overcoming learning difficulties, increasing learning motivation, and improving database project skills. Integrating problem-based and project-based learning can inform curriculum design, improve teaching strategies, and the results of this study can be used as evaluation material for teachers in choosing active learning approaches.

INTRODUCTION

The advancement of software technology in data processing has driven the need for innovative learning approaches to equip students with database design and processing skills, alongside 21st-century competencies (Khoiriyah & Husamah, 2018; Partono et al., 2021). Database courses encompass both theoretical and practical aspects of data manipulation, focusing on designing conceptual databases that reflect real-world information systems. These designs, often depicted through Entity Relationship Diagrams (ER-D) and normalization techniques, are implemented using database applications such as MySQL and Oracle, covering all aspects of Database Management Systems (DBMS) (Liu, 2024).

Despite their importance, database courses pose challenges for students, particularly in mastering relational data design, eliminating redundancy, and ensuring data integrity (Chen et al., 2016). These procedural difficulties often stem from limited understanding and complex real-world applications. While the Problem-Based Learning model aids in developing analysis and design skills, significant gaps remain in achieving essential database competencies and addressing students' learning difficulties (Ahdhianto et al., 2020; Demirören et al., 2020; Saad & Zainudin, 2022). Students often struggle with database operations, particularly managing large volumes of data, identifying anomalies, avoiding redundancy, and ensuring data integrity. These challenges stem from students' limited

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understanding of database modeling concepts and their inability to interpret methods derived from complex real-world cases. This indicates that learning challenges cannot be fully addressed solely by applying the Problem-Based Learning model. The absence of appropriate learning media and the application of less effective learning models further hinder students' achievement of core competencies and soft skills. Current implementations of Problem-Based Learning do not sufficiently provide the learning challenges needed to engage students (Handayani & Koeswanti, 2021; Khoiriyah & Husamah, 2018).

A learning model is a structured framework guiding classroom instruction, designed based on the characteristics of both the course and students (Elisabet et al., 2019; Gomez-del Rio & Rodriguez, 2022). Effective models in technical and vocational education and training combine learning with real-world practice (Real-World Learning) and emphasize problem-solving as a key 21st-century competency (Lewis, 2023). Project-based learning aligns well with technical and vocational education and training by integrating problem discovery and real-world applications, preparing graduates to meet industry demands (Scuderi et al., 2023). The Problem and Project-Based Learning model addresses database learning challenges, fostering competencies and soft skills such as critical thinking and collaboration.

The development of the Problem and Project-Based Learning model was informed by assessments of learning needs, student characteristics, and database course requirements. Combining Problem-Based Learning and Project-Based Learning provided a theoretical foundation to achieve cognitive, affective, and psychomotor competencies, supported by theories such as constructivism, behaviorism, cognitivism, connectivism, and andragogy. These approaches address self-management, inquiry discovery, and students' psychological needs (Göncz, 2017; Sharma et al., 2020; Wachida et al., 2021). While Problem-Based Learning focuses on problem-solving, it alone does not fully develop database design, communication, and reporting skills aligned with industry standards. Project-Based Learning complements this by integrating real-world database projects, fostering confidence through product demonstrations, and encouraging teamwork. Project-Based Learning engages learners in designing, planning, executing, and evaluating projects, providing practical experience and addressing industry challenges (Gomez-del Rio & Rodriguez, 2022; Kuppuswamy & Mhakure, 2020).

Project-Based Learning effectively develops skills in reporting, communication, technical database design, creativity, and information technology. However, some competencies remain challenging to achieve through Project-Based Learning alone and require integration with other learning models (McLoone et al., 2016; Nair & Suryan, 2020). To address these gaps, Project-Based Learning is combined with Problem-Based Learning, resulting in the Problem and Project-Based Learning model. This integrated approach effectively improves database design skills, learning motivation, and the development of 4C competencies critical thinking, creativity, collaboration, and communication. Tailored to address the challenges of Diploma III Informatics Management students, Project-Based Learning supports key skills such as problem-solving, self-management, and report writing.

METHODS

The development of the Problem and Project-Based Learning model follows a Research and Development approach. Research and Development is a model development methodology that includes effectiveness testing of both technical aspects and the learning process (Dwivedi et al., 2021; Fayola, 2023; Zhao, 2023). The model development process adopts Thiagarajan's 4D framework, which consists of four stages: Define, Design, Develop, and Disseminate. This framework emphasizes the planning and development of programs as products that effectively achieve their intended objectives (Simanjuntak & Christianus, 2024). The research and development procedure within the 4D framework involves systematic stages of activities (Anggraini et al., 2024). This structured approach is designed

to address learning challenges by developing learning media that align with the needs and characteristics of students (Arywiantari et al., 2015).

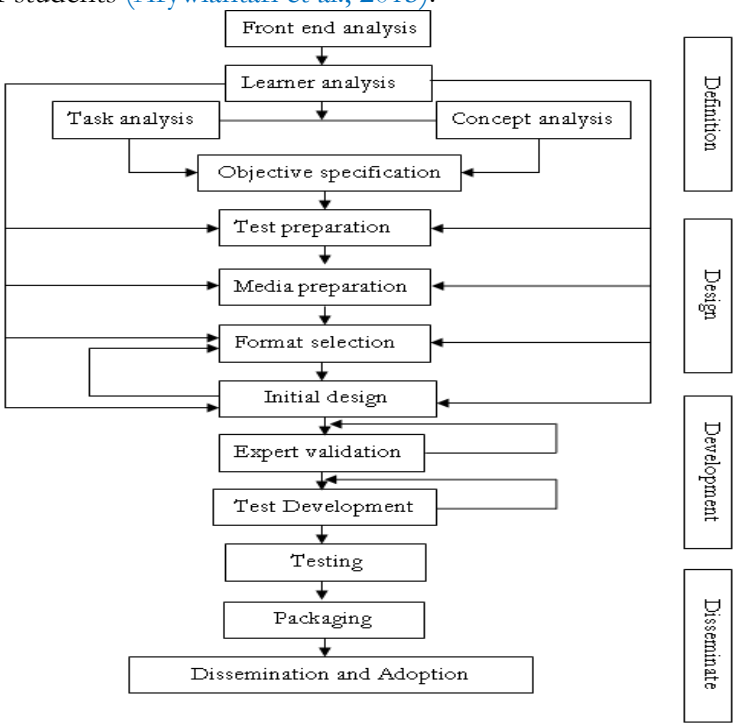

Fig 1. Thiagarajan's 4D Research and Development Procedure

Research activities in the definition stage include front-end analysis. This analysis begins with a review of the curriculum to identify competencies that are challenging for students to achieve, along with the learning processes and media to be developed. An analysis of student characteristics was also conducted, identifying difficulties such as cooperation, collaboration, communication, creativity, and challenges in understanding the material and preparing case study research reports. A concept analysis of course materials was performed to pinpoint key and supplementary materials that are relevant and necessary for instruction (Soleman et al., 2020; Susanti et al., 2023). The material was then organized systematically to facilitate student comprehension. Task analysis identified the essential skills students must acquire in relation to database competencies. Additionally, instructional objectives were specified to formulate learning outcomes, course outcomes, sub-achievements, and expected behaviors, resulting in course instructions, a course syllabus, and a semester learning plan.

During the design stage, researchers developed a conceptual framework for the model and associated learning tools. In Thiagarajan's 4D framework, the design stage comprises four key activities: (1) creating criterion-referenced tests to assess students' initial abilities, (2) designing learning media aligned with the material and student learning difficulties (media selection), (3) formulating the learning syntax, reaction principles, instructional impacts, and accompanying impacts of the developed model (format selection), and (4) structuring the format and presentation steps. In the development stage, expert appraisals were conducted to test the feasibility of the developed product. This was followed by product trials with students, iterative revisions, and refinements until a development product meeting the research objectives was achieved. The procedure for developing the Problem and Project-Based Learning model for database courses included testing the effectiveness of the revised product after classroom implementation.

The population and sample for the research comprised active students in the Informatics Management study program. The test group consisted of 30 students who studied using the Problem and Project-Based Learning model, while the control group included 30 students who studied conventionally in the database course. Product trials of the Problem and Project-Based Learning model incorporated scaffolding and constructivist activities in the classroom, as well as structured guidance in laboratories. The instrument used

to test the effectiveness of the developed learning model was a Likert scale numerical instrument.

RESULT AND DISCUSSION

The development of the Problem and Project-Based Learning model encompasses learning products, support systems, social systems, accompanying effects, and instructional guidelines. The syntax of the Problem and Project-Based Learning model is structured into three stages: the preliminary stage, the core activities stage, and the closing activities stage. Each stage consists of two instructional phases tailored for database learning. By integrating problem-based learning and project-based learning models, the Problem and Project-Based Learning framework produces six instructional phases. These phases are designed to enhance learning motivation, particularly for passive students or those facing learning difficulties. Intense, guided project work fosters learning satisfaction, alleviates the mental burden of tackling challenges during the learning process, and promotes student autonomy in learning (Hadiati et al., 2023; Mardiana et al., 2022).

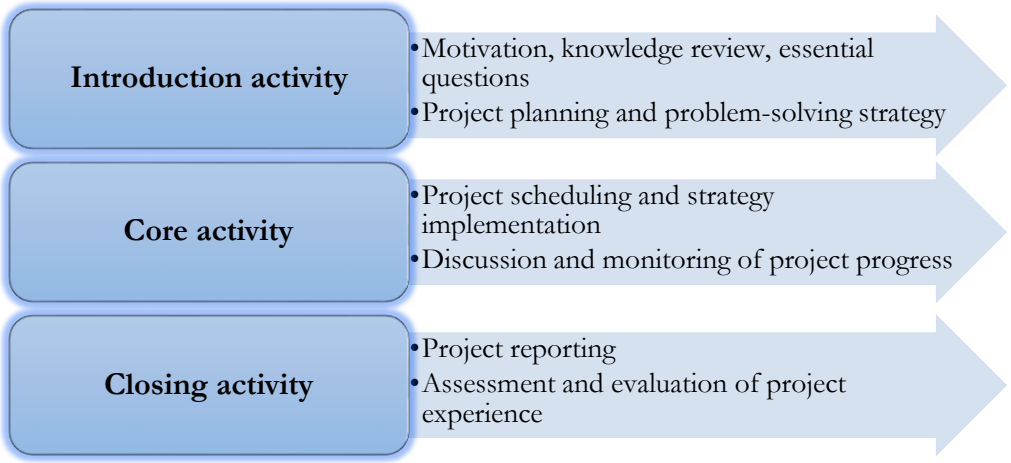

Table 1. Condenser data of steam power plant

Each phase of the developed Problem and Project-Based Learning model syntax is applied in classroom settings and supplemented with practical learning in the laboratory. Project-based learning in the laboratory allows students to become familiar with handling instruments and devices, as well as collaborating in teams with diverse abilities and working patterns, thereby strengthening their understanding of lecture concepts. Project-based learning enhances competencies across cognitive, affective, and psychomotor domains, improves design performance, increases intrinsic motivation, and broadens students' future insights and career prospects (Khilmiyah & Wiyono, 2021).

The integration of Problem-Based Learning and Project-Based Learning is informed by an analysis of student characteristics, particularly those with learning difficulties and low competency achievements, as well as the requirements of courses focused on solving information system data processing problems. The motivation and skills necessary for database design in project teams align well with the syntax of the integrated models. Active learning and creativity are fostered in project-based activities, promoting innovation and encouraging student autonomy in learning. While project-based learning emphasizes constructing new knowledge and fostering creativity, problem-based learning focuses on the application of knowledge for problem-solving (Hasani et al., 2017; McLoone et al., 2016; Nair & Suryan, 2020; Sharma et al., 2020).

The effectiveness test analysis was conducted to evaluate the impact of the Problem and Project-Based Learning model in the database course. This analysis compared two learning groups: the treatment group, which utilized the Problem and Project-Based Learning model, and the control group, which followed conventional learning methods. The research employed a Non-Equivalent Control Group Design, where participants in both groups were selected non-randomly (Abidin et al., 2020; Ahdhianto et al., 2020; Khoirudin, 2022). To

determine the effectiveness of the developed model, a descriptive analysis was conducted by examining the average scores of the groups and the differences (gains) between their values. The effectiveness test specifically assessed student learning outcomes across the cognitive, affective, and psychomotor domains. A summative evaluation was carried out to comprehensively measure learning achievements, providing insights into the model's ability to improve overall student performance in the database course.

Table 1 Analysis of Effectiveness Test of Learning Outcomes of Both Student Groups

Competency domain	Class (@30 students)	Average Learning Outcome	Normality of effectiveness data (Kolmogorof Smirnov Test)	Hypothesis Test Score (Levene Statistics)	t count > t table	Significance level
Cognitif	Experiment	80,90	0,858	0,001	4,806>2,000	95%
	Control	65,93	0,738			
Affective	Experiment	125,28	0,858	0,055	6,689>2,000	95%
	Control	85,13	0,484			
Psychomotor	Experiment	123,83	0,251	0,483	6,499>2,000	95%
	Control	95,40	0,484			

The table shows that the student group in the treatment class obtained an average learning outcome of 80.90 and 65.93 in the control class. Both data groups have normal data assumptions using the Kormogorov Smirnov Test with a significance of 0.858 for the treatment group and 0.738 for the control group. Hypothesis testing with the levene statistical test has a score of sig. 0.001. Thus Ha which says there is a difference in cognitive learning outcomes of students taught withProblem and Project Based Learning model is better than students who learn conventionally. The significance level is 95%, because t count> t table (4.806> 2.000).

Students affective competence is measured to determine the level of mastery of student attitudes and behavior. The data was collected based on a valid and reliable Likert scale behavior measurement questionnaire with a total of 31 questions. The table shows that the treatment class students get the average learning outcomes based on attitude is 125.28 and 85.13 in the control group which means that the treatment class is higher than the control class. Hypothesis testing conducted with the statistical levene test has a sig score. 0.055 Thus Ha which says there is a difference in the affective learning outcomes of students taught with the Problem and Project Based Learning learning model better than students who learn conventionally is accepted at the 95% significance level, because t count> t table (6.689> 2.000). Students' psychomotor competence is measured to determine the level of mastery of student practice. Data was taken based on a Likert scale observation sheet used by lecturers with a total of 37 assessment items.

While the test of the effectiveness of the psychomotor domain in the treatment class, the average student practical learning outcomes are 123.83 and 95.40 in the control class, which means that the treatment class is higher than the control class. Hypothesis testing with the levene statistic test has a sig score. 0.438 Thus Ha which says there is a difference in the psychomotor learning outcomes of students taught with the Problem and Project Based Learning Problem and Project-Based Learning learning model better than conventional learning students is accepted at the 95% significance level, because t count> t table (6.499> 2.000).

CONCLUSION

Research and development of Problem and Project Based Learning models based on the problem of learning difficulties that cause failure to achieve course competencies are indicated due to conventional learning. Low motivation to learn, conventional learning, and unsystematic learning methods cause non-achievement of course competencies and soft skills that are relevant to 21st century learning competencies. The development of the

Problem and Project Based Learning model uses the 4D development procedure by Thiagarajan. Learning models and products are designed with a scientific framework and procedures, based on needs analysis and in-depth studies, and have systematic instructional stages so as to effectively improve student learning outcomes in the cognitive, affective, and psychomotor domains and effectively improve soft skill competencies such as cognition, creativity, collaboration, and communication. The results of the effectiveness test of the Problem and Project-Based Learning model show that the group of students who study in the treatment class (experiment) has an average value of learning outcomes in the three learning domains higher than students who study in the control class (conventional class). The developed Problem and Project-Based Learning model can have implications for the utilization of digital technology in the era of society 5.0 in the Problem and Project-Based Learning model as a sustainable development.

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