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The Effectiveness of Playful Learning Design on Learning Outcomes and Cognitive Load in Junior High School Informatics

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Abstract: This study aims to evaluate the effectiveness of pedagogical PSD adaptation in improving learning outcomes while managing junior high school students' cognitive load in Informatics learning. This research employed a quantitative approach using a quasi-experimental design with a non-equivalent control group pretest–posttest design. The sample consisted of 56 eighth-grade students who were divided into an experimental group implementing the PSD method and a control group using the Think Pair Share method. Data were collected through pretests, posttests, and cognitive load questionnaires. The data were analyzed using descriptive statistics to summarize learning outcomes, followed by the Shapiro–Wilk test to examine data normality. Since the posttest data were not normally distributed, the Mann–Whitney U test was conducted to compare learning outcomes between the experimental and control groups. Cognitive load was measured using a questionnaire based on Cognitive Load Theory (CLT) and analyzed descriptively through mean scores across three dimensions: intrinsic, extraneous, and germane cognitive load. The module review results indicated that the adapted PSD module was considered appropriate by six Informatics teachers in terms of content, language, and alignment with student characteristics. The statistical analysis revealed a significant difference between the two groups, with the experimental group achieving higher learning outcomes than the control group ($p < 0.05$). Regarding cognitive load, both groups demonstrated low intrinsic and extraneous cognitive loads, while the experimental group exhibited a higher germane cognitive load. These findings suggest that PSD adaptation effectively improves learning outcomes while promoting more optimal cognitive engagement among students in Informatics learning.

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Introduction

Learning at the junior high school level should be designed in a pleasant environment because students are in early adolescence, a phase prone to shifts in learning motivation and strongly influenced by school learning experiences (Raufelder & Kulakow, 2021). A learning approach that combines active engagement with playful elements has a strong empirical foundation in supporting educational effectiveness, thus enjoyable learning can be understood as a strategy that contributes to engagement and outcomes, rather than merely an entertainment activity (Blinkoff et al., 2023). Academic emotional aspects such as enjoyment are also linked to student engagement, making a pleasant learning environment a key factor in maintaining student participation (X. Zhang et al., 2024). Indonesia's Merdeka Curriculum further reinforces this learner-centered approach, opening opportunities for more active and

Vol. 13 No. 3 : July 2026
E-ISSN: 2722-4627
pp. 1142-1152

relevant learning strategies tailored to junior high school students (Kemendikbudristek, 2022).

However, enjoyable learning must still be directed toward achieving learning objectives and must balance elements of joy with cognitive challenges and meaningful thinking processes (Nesbitt et al., 2023). From the perspective of Cognitive Load Theory (CLT), poorly structured instructional design has the potential to increase extraneous cognitive load, thereby hindering information processing and the understanding of core concepts (Skulmowski & Xu, 2022). This aligns with the push toward deep learning, that is, learning that emphasizes conceptual understanding, connections between ideas, and reflective application of knowledge, rather than merely procedural task completion (Nana & Brenya, 2024).

In junior high school informatics education, several approaches have been widely applied. Problem-oriented learning supports computational thinking but may become less effective when students lack sufficient conceptual understanding, potentially increasing cognitive load (Bai et al., 2021). Project-Based Learning (PjBL) can enhance engagement and outcomes, but its effectiveness heavily depends on learning tools and strong teacher guidance (Zhang & Ma, 2023). Meanwhile, game-based learning increases motivation, but remains dominated by a "learning by playing" approach, leaving limited room for students to independently manage their learning strategies(Videnovik et al., 2023). These approaches have strong potential yet still require a design capable of guiding students to understand concepts gradually. Therefore, an informatics learning design that is both enjoyable and meaningful is needed, which theoretically can be addressed through Playful Study Design (PSD). Informatics at the junior high school level emphasizes conceptual understanding and information analysis, requiring students to process abstract and context-dependent information that can be cognitively demanding (Mutaqin et al., 2026). Without appropriate instructional design, this abstract nature may increase extraneous cognitive load (Skulmowski & Xu, 2022).

PSD is a way for students to proactively design their learning activities to be more fun or more challenging (Costantini et al., 2025), interpreted in this study as the ability to select learning strategies and goals from provided alternatives based on individual abilities and preferences. PSD is associated with increased study engagement and supports the achievement of learning goals (Wang et al., 2023). However, research on PSD has developed primarily in higher education contexts, and empirical evidence regarding its impact on CLT in junior high school informatics education remains limited (Costantini et al., 2025; Wang et al., 2023), indicating a clear research gap. Therefore, this study was implemented with pedagogical adaptations tailored to junior high school students, conducted in a structured manner with teacher guidance without altering the core principles of PSD. Therefore, this study aims to evaluate the effectiveness of pedagogical PSD adaptation in improving learning outcomes while also managing junior high school students' cognitive load in Informatics learning. PSD has the potential to address cognitive load issues by allowing students to regulate the complexity of their learning tasks in accordance with their cognitive capacity. Through the selection of strategies and goals that align with their prior knowledge and individual preferences, students are less likely to experience unnecessary cognitive burden (extraneous load). As a result, PSD can facilitate more efficient information processing, which is essential for optimizing learning in subjects that require complex thinking, such as Informatics.

Vol. 13 No. 3 : July 2026
E-ISSN: 2722-4627
pp. 1142-1152

Research Method

This study employed a quantitative approach using a quasi-experimental design of the non-equivalent control group type with a pretest–posttest model. This design was chosen because student placement had already been determined by the school into fixed classes, making randomization impossible. The two available classes were used as the intervention group and the control group, both receiving instruction on equivalent computer science material but differing in learning strategies applied. The intervention group followed PSD-based instruction, while the control group followed Think, Pair, Share (TPS)-based instruction. TPS was selected as the comparison condition because it was the instructional strategy chosen by the teacher to encourage student discussion and active participation during the lesson. The study participants consisted of 56 junior high school students selected through convenience sampling based on class availability. The criteria for participants included active eighth-grade students taking the Computer Science course during the study semester and willing to participate in the entire study.

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Exsperimental (n =28)	O1	X_1 (PSD-based Informatics Learning)	O2
Control (n =28)	O3	X_2 (TPS-based Informatics Learning)	O4

This research was carried out through several phases. The preparation phase included determining the subjects for both groups, developing PSD-based learning modules, and designing research instruments consisting of learning outcome tests and a CLT questionnaire. The developed modules were reviewed through interviews with junior high school computer science teachers to assess their suitability in terms of content, language, and alignment with student characteristics, and revised accordingly based on teacher feedback. Subsequently, a pretest was given to both groups to identify students' baseline abilities. The intervention stage followed, during which the experimental group was provided with PSD-based learning activities, while the control group received TPS-based instruction. After the instructional sequence was completed, a posttest was administered to measure student learning outcomes, followed by administration of the CLT questionnaire to examine the level of cognitive load experienced by students in each group. The final stage involved data analysis and interpretation, including descriptive statistics, normality tests, and between-group comparison, as well as discussion relating findings to theory and previous studies.

The research instruments included learning outcome tests and a CLT questionnaire, supplemented by an observation sheet to assist in monitoring the learning process. The learning outcome tests consisted of a pretest and posttest, each comprising 20 multiple-choice questions designed based on the same content and indicators. The CLT questionnaire was designed as a Likert scale with a rating range of 1–4, administered on paper, covering three dimensions: Intrinsic Cognitive Load (ICL), Extraneous Cognitive Load (ECL), and Germane Cognitive Load (GCL), adapted from Krieglstein et al. (2023).

Table 2. Cognitive Load Questionnaire (CLQ)

Cognitive Load	Statements
ICL	
ICL1	This lesson feels difficult to me.
ICL2	The explanations in this lesson confuse me.
ICL3	The material in this lesson feels complicated.

Jurnal Paedagogy:
Jurnal Penelitian dan Pengembangan Pendidikan
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Vol. 13 No. 3 : July 2026
E-ISSN: 2722-4627
pp. 1142-1152

ICL4	There is a lot of content in this lesson, and it is difficult to understand.
ICL5	If I haven't studied this before, the lesson becomes even more difficult.
ECL	
ECL6	I have trouble following the sequence of explanations in this lesson.
ECL7	I'm confused about how one part of the material relates to another.
ECL8	The material is explained in a way that's not very clear.
ECL9	I have trouble identifying the important parts of this material.
ECL10	The way this material is explained makes it hard for me to focus.
GCL	
GCL11	I'm trying hard to think about this lesson.
GCL12	This lesson encourages me to think more deeply.
GCL13	I'm trying to make sure I really understand.
GCL14	I'm trying to connect this lesson to things I already know
GCL15	I feel like I've understood this lesson well.
GCL16	This lesson has expanded my knowledge.
GCL17	I can apply the material I've learned quickly and correctly.

(Krieglstein et al., 2023)

The mean score for each CLT dimension is interpreted by referring to category intervals as presented in Table 3.

Table 3. Criteria for Interpreting Cognitive Load Scores

Interval	Category
1.00 – 1.75	Very Low
1.76 – 2.50	Low
2.51 – 3.25	High
3.26 – 4.00	Very High

(Sari et al., 2025)

Hypothesis testing was conducted to examine differences in students' learning outcomes between the experimental and control groups based on posttest scores. Prior to hypothesis testing, a normality test using the Shapiro–Wilk test was performed to determine whether parametric or nonparametric analysis should be applied. Since the data were not normally distributed, the Mann–Whitney U test was used to compare the two groups. The hypotheses tested were H_0: there is no significant difference in learning outcomes between groups, and H_1: there is a significant difference in learning outcomes between groups. All decisions were based on a significance level of 0.05.

Results and Discussion

Playful Study Design (PSD) Module Design

The adapted modules were reviewed through interviews with six junior high school informatics teachers to assess their suitability in terms of content, language, and alignment with student characteristics. Overall, the teachers agreed that the PSD-based modules were appropriate, reflected PSD principles, and met students' needs.

However, two areas for improvement were identified: the lack of clearly defined learning phases and the excessive number of learning strategies, which was reduced from five to three to improve clarity. The interview data were analyzed using thematic analysis, involving all six teachers (G1–G6). Table 4 presents selected excerpts from G2, G4, and G5, as their responses consistently highlighted similar revision needs.

Vol. 13 No. 3 : July 2026
E-ISSN: 2722-4627
pp. 1142-1152

Table 4. Overview of Interview Findings (Areas Requiring Revision)

Aspects Discussed	G2	G4	G5
Structure of learning activities	"In this module, it is not yet clear which activities are the opening, main, and closing activities, so this needs to be clarified further."	"The division of learning phases should be made more distinct so that the flow is easier to understand."	"This module is not yet like a typical module, there should be descriptions of the learning activities, and the syntax should be clarified and made simpler for easier understanding avoid too much text"
Learning Strategies and Objectives	"There are too many learning strategies used; this may be difficult for middle school students to understand."	"The learning strategies should be simplified, selecting only those that are easiest for students to grasp. They should then be aligned with the objectives so that teachers and students do not become confused."	"If there are too many strategies, I'm concerned students will become confused while following the lesson."

Following revisions based on teacher feedback, the Playful Study Design (PSD) based learning module was refined in terms of the structure of learning activities and the simplification of learning strategies and objectives. The revised module is organized in a more structured manner, clearly outlining opening, main, and concluding activities, along with instructional strategies that have been simplified into three main sections on the Student Worksheet (LKPD). The intervention module consists of two parts: an orientation and guided practice module, and a self-directed application and strategy optimization module. The detailed design of the intervention module is presented in Table 5.

Table 5. Design of the Playful Study Design Intervention Module for Junior High School Informatics Education

Module	Topic/Learning Content	PSD Activities
1) Orientation and Practice in Playful Study Design for Informatics Education	Opening Activities 1) The lesson begins with an introduction to the objectives, classroom rules, and activity flow to help students develop an initial understanding of the learning process. 2) The teacher conducts an opening activity in the form of a casual discussion and relates the material to the students' experiences. Main Activities 1) The teacher introduces the concept of Playful Study Design (PSD) as a student learning strategy, emphasizing two main components: designing fun and designing challenge. The teacher explains that the playful element serves to support focus, engagement, and learning comprehension, rather than merely providing entertainment. 2) The teacher facilitates a guided discussion to help students understand the role of fun and challenge in maintaining focus during	1) Students select learning strategies and difficulty levels provided in the worksheets, where each strategy is integrated with specific learning objectives as a form of challenge. 2) Students apply this combination while completing exercises with intensive guidance from the teacher. 3) Students provide a brief oral reflection on the appropriateness of the learning strategies used and the achievement of learning objectives.

Vol. 13 No. 3 : July 2026
E-ISSN: 2722-4627
pp. 1142-1152

	learning, and introduces the setting of simple learning goals as a form of self-regulation. 3) The teacher then introduces various options for concrete learning strategies and goals that are appropriate for middle school students and relevant to the learning material. 4) The teacher presents the material/concepts according to the topic of Session 1, accompanied by examples and guided exercises; students apply the selected PSD strategies while taking notes and during exercises with intensive teacher guidance.	
	Closing Activities	
	1) The teacher provides a brief summary of the key learning points. 2) Students give a brief oral reflection on the effectiveness of their learning strategies and the achievement of their learning goals. 3) The teacher acknowledges the students' efforts and encourages them to continue trying appropriate learning strategies.	
2) Independent Implementation and Optimization of Playful Study Design	Opening Activities	1) Students apply and adapt the selected combination of learning strategies and levels of challenge to complete computer science learning tasks more independently. 2) Students strive to achieve learning objectives integrated into the selected combination of strategies. 3) Students engage in structured reflection on their experience using PSD-based learning strategies.
	1) The teacher briefly reviews the concept of Playful Study Design, particularly "designing fun" and "designing challenges." 2) Students are given the opportunity to adjust or change their learning strategies and learning goals based on their experiences in the previous module. 3) Students apply Playful Study Design more independently in their computer science learning activities.	
	Main Activities	
	1) The teacher presents advanced material in line with the lesson topic. 2) Students complete text analysis assignments more independently. 3) Students consciously apply and adapt the selected PSD strategies according to the requirements of the assignment. 4) The teacher acts as a facilitator and provides assistance only when needed. 5) The results of the analysis are discussed to strengthen the arguments and ensure the accuracy of the classifications.	
	Closing Activities	

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Jurnal Penelitian dan Pengembangan Pendidikan
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Email:paedagogy@undikma.ac.id

Vol. 13 No. 3 : July 2026
E-ISSN: 2722-4627
pp. 1142-1152

1) The teacher provides a brief summary of the material and the learning process.
2) Students engage in structured reflection on their experience using PSD-based learning strategies and the achievement of learning objectives.
3) The teacher emphasizes the benefits of using PSD strategies to support learning in computer science.

Based on Table 5, the intervention module that has been developed consists of two main stages, namely the orientation and guided practice stage as well as the independent application stage. Specifically, student autonomy is reflected in both modules. In Module 1, when students are given exercises, they are already free to independently choose their own learning strategies and difficulty levels based on their individual abilities, but at this stage the teacher still provides intensive guidance as students are in the orientation phase and are being introduced to each available strategy. In Module 2, students are equally free to choose their strategies and challenge levels when assigned tasks, but are expected to apply them more independently and are also encouraged to adjust or replace their strategies if they feel the previous approach was insufficient or if they wish to take on a greater challenge.

The module has been systematically structured to include opening, core, and closing activities, and is supplemented with reflection activities to support student engagement and self-regulation. Thus, the revised module is deemed ready for use in the implementation of the learning intervention.

Tests of Learning Outcomes

Table 6. Recapitulation of Statistical Tests of Learning Outcomes

Test Type	Indicator/Statistic	Experimental Class		Control Class	
		Pretest	Posttest	Pretest	Posttest
Descriptive Statistics	Mean	64.11	88.57	59.64	75.89
	Median	65.00	90.00	60.00	82.50
	Minimum-Maximum	40-85	65-100	20-90	45-100
	Std. Deviation	10.976	9.705	17.209	16.219
Normality Test	Shapiro-Wilk Sig.	0,204	<0,001	0.389	0.033
	Conclusion	Normal	Not Normal	Normal	Not Normal
Mann-Whitney U Test	Sig. (2-tailed)	<0.001			
	Conclusion	There is a Significant Difference			

Students in the experimental class achieved higher posttest scores and showed more consistent performance than those in the control class. The results indicate that PSD-based instruction effectively improves learning outcomes in junior high school Informatics.

Measuring Cognitive Load: Cognitive Load Theory (CLT)

Table 7. Mean Scores and Interpretation of Cognitive Load Theory (CLT)

	Experimental Class		Control Class	
	Mean	Interpretation	Mean	Interpretation
Intrinsic Cognitive Load	2,21	Low	1,81	Low
Extraneous Cognitive Load	2,02	Low	1,64	Very Low
Germane Cognitive Load	3,31	Very High	2,98	High

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Jurnal Penelitian dan Pengembangan Pendidikan
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Email:paedagogy@undikma.ac.id

Vol. 13 No. 3 : July 2026
E-ISSN: 2722-4627
pp. 1142-1152

Both classes maintained low intrinsic and extraneous cognitive load, indicating that the learning material was appropriately designed and presented. However, the experimental class showed higher germane cognitive load, suggesting that PSD-based learning promotes deeper cognitive engagement and more active knowledge construction.

Discussion

Learning Outcomes

The findings of this research indicate that the average posttest scores of the experimental group exceeded those of the control group, indicating that Playful Study Design (PSD)-based instruction has the potential to contribute positively to student learning outcomes. The results further imply that integrating enjoyable and purposeful learning elements can motivate students to participate more actively in the learning process, which has been linked to improved academic achievement in various studies (Li & Kangas, 2024; Ruiz et al., 2024).

This improvement in learning outcomes is closely linked to the characteristics of PSD, which provide students with the opportunity to choose and adapt learning strategies according to their abilities and preferences. This flexibility in the learning process fosters greater cognitive engagement among students as they are actively involved in controlling their own learning process (Kangas & Siklander, 2023). Through this process, students do not merely passively receive content but actively participate in learning decisions, which can support deeper conceptual understanding (Li & Kangas, 2024). Additionally, providing challenges in learning, as widely discussed in the context of gamification, is known to enhance intrinsic motivation and encourage greater learning effort (Ruiz et al., 2024). This condition helps students become more accustomed to handling the complexity of the material during the learning process, thereby improving their readiness to tackle problems. Thus, the learning strategies chosen by students in PSD can contribute to improved learning outcomes.

These findings align with previous research showing that integrating fun and challenge in learning increases engagement and learning outcomes (Liu et al., 2025). Furthermore, research by Blinkoff et al. (2023) also indicates that a playful learning approach can improve the quality of student engagement and strengthen conceptual understanding, particularly when students' intrinsic motivation serves as a driving force (Wijnia et al., 2024). In this study, PSD was implemented in a structured manner with teacher guidance as a form of pedagogical adaptation for the junior high school level without altering its core principles. This approach aligns with Costantini et al. (2025), who argue that the principles of playful study design can still function effectively when adapted to different learning contexts, provided that their core elements are maintained.

Cognitive Load Theory (CLT)

The results of the analysis of the three components of Cognitive Load Theory (CLT) reveal differences in cognitive load between the experimental and control classes. Regarding the Intrinsic Cognitive Load (ICL) component, both classes fell into the low category, indicating that the computer science learning material presented was not perceived as overly difficult by the students in either class. This indicates that the complexity of the material remains appropriate for the students' abilities, thus not acting as a barrier to the learning process. Intrinsic cognitive load arises from the inherent complexity of the material itself. The more interconnected parts of the material that must be understood simultaneously, the harder the students' brains must work to process them (Sweller, 2023).

Although both were low, the experimental class showed a slightly higher ICL score than the control class. This is understandable because in PSD-based learning, students are

Vol. 13 No. 3 : July 2026
E-ISSN: 2722-4627
pp. 1142-1152

asked to choose their own learning strategies and goals that align with their abilities and preferences, including selecting higher-level challenges if they feel capable. This selection process naturally places students at a slightly higher level of complexity. However, because these choices are provided in a structured manner with teacher guidance, the resulting cognitive load remains manageable. This aligns with findings that when teachers provide clear structure while supporting students' freedom in learning, the cognitive load they experience tends to decrease, and their engagement in learning actually increases (Evans et al., 2024).

Regarding the Extraneous Cognitive Load (ECL) component, the experimental class fell into the low category, while the control class fell into the very low category. The low ECL in both classes indicates that the method of instruction did not confuse the students. The more of the students' cognitive effort is expended on irrelevant matters due to poor instructional design, the less cognitive capacity remains for truly understanding the content (Surbakti et al., 2024). The slightly higher ECL scores in the experimental class compared to the control class are related to students' initial adaptation to the PSD mechanism. However, since the ECL scores remained in the low category, this increase did not negatively impact the learning process. Overall, the PSD-based learning design successfully prevented students from being burdened by matters outside the core material. This finding is also supported by the research of Wang et al. (2023), which shows that when learning tasks are designed to be more enjoyable through PSD, students enjoy the learning process more, so their attention is not divided and remains focused on the learning objectives.

Different from the two previous components, Germane Cognitive Load (GCL) showed the most notable results. The experimental class fell into the very high category, while the control class fell into the high category. A high GCL is the most positive and desirable condition in the learning process, as it reflects how actively students are actually thinking and constructing new understanding. GCL is the cognitive effort expended by students to truly understand the material and store it as long-term knowledge. This effort is directly related to the process of forming knowledge schemas and students' higher-order thinking skills (Ayvaz-tuncel & The, 2024). This difference indicates that PSD-based learning successfully encouraged students to think more deeply during the learning process, closely tied to the core principle of PSD, which is to encourage students to design their own learning activities by choosing from several available options, making the process both more enjoyable and more challenging. When learning tasks become more engaging and challenging through PSD, students' motivation increases, making them more enthusiastic and engaged, which ultimately enhances their ability to solve problems and achieve learning objectives (Wang et al., 2023). This finding indicates that optimal learning occurs when germane cognitive load is higher than intrinsic and extraneous load, allowing students to focus more on meaningful understanding (Januchta et al., 2022).

Conclusion

The PSD-based learning modules developed were found to be suitable for junior high school informatics education. PSD-based learning proved effective in improving student learning outcomes compared to the Think, Pair, Share method. Based on the CLT framework, the experimental class demonstrated significantly higher germane cognitive load, indicating deeper cognitive engagement. These findings suggest that PSD can serve as a practical strategy for informatics teachers to encourage students to continuously strive toward higher levels of challenge over time, thereby promoting deeper and more meaningful learning. For

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Jurnal Penelitian dan Pengembangan Pendidikan
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Vol. 13 No. 3 : July 2026
E-ISSN: 2722-4627
pp. 1142-1152

curriculum developers, integrating elements of fun and challenge into instructional design is a cognitively meaningful approach that supports learning outcomes. More broadly, this study adds empirical evidence that PSD is an effective instructional strategy in junior high school informatics education, contributing to the growing global literature in this field.

Recommendation

For practitioners, informatics teachers who implement the PSD module are advised to provide clear and detailed instructions regarding the available learning strategies and challenge levels to avoid triggering extraneous cognitive load. Additionally, teachers should allow sufficient adaptation time across multiple meetings so that students can gradually become familiar with the PSD approach and apply their chosen strategies more independently

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