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Improving Student Motivation in Mathematics Learning Thro

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Abstract

This study aims to analyze the effectiveness of gamification approaches integrated with Problem-Based Learning (PBL) in increasing students' learning motivation in mathematics learning. Low motivation to learn mathematics is a common problem in Indonesia, as evidenced by the results of PISA 2022 which shows that Indonesia's mathematics score only reaches 379 out of the OECD average score of 487. This study uses a quasi-experimental method with pretest-posttest control group design with the research subjects of 60 high school students in class X who are divided into experimental and control groups. The research instruments included a mathematics learning motivation questionnaire, a mathematical problem-solving ability test, an observation sheet, and an interview guideline. The results showed that the integration of gamification with PBL significantly increased students' learning motivation with an N-Gain of 0.68 (medium category), created a more interactive and enjoyable learning experience, and helped students understand mathematical concepts more deeply through contextual problem-solving. Gamification elements such as points, badges, levels, and leaderboards successfully create a competitive yet collaborative learning environment, while PBL encourages students to think critically and creatively in solving mathematical problems. Statistical tests showed significant differences ($p < 0.05$) between the experimental and control groups, indicating the effectiveness of this approach in increasing motivation to learn mathematics.

INTRODUCTION

Mathematics learning in Indonesia still faces significant challenges, especially related to the low motivation of students to learn. The 2022 Programme for International Student Assessment (PISA) data shows that Indonesia's average math score only reaches 379, far below the average score of Organisation for Economic Co-operation and Development (OECD) countries which reaches 487. This condition indicates the need for innovation in mathematics learning to improve student motivation and learning outcomes (Abramovich et al., 2019).

One of the main factors of low motivation to learn mathematics is the perception of students who perceive mathematics as a difficult, scary, and unpleasant subject. Research shows that a lack of interest in mathematics lessons makes students lazy to learn mathematics, which has an impact on their learning achievement (Syuhada et al., 2023). Conventional learning that focuses on memorizing procedures and routine practice tends to hinder students' ability to achieve true mathematical prowess.

Gamification as an innovative learning approach has been proven to be effective in increasing student motivation and engagement. Recent research shows that gamification significantly affects motivation by facilitating the assimilation of knowledge, improvement of skills, and academic competence of students (Meylani, 2025). Gamification elements such as points, badges, levels, challenges, and leaderboards create a more engaging, interactive, and competitive learning experience.

On the other hand, Problem-Based Learning (PBL) is a constructivist learning approach that places students as active learners through contextual problem-solving. PBL has the potential to increase student engagement, encourage critical thinking, and increase motivation by linking abstract mathematical theory with real-life applications (Wiradnyana et al., 2024).

The urgency of this research is underscored by three factors. First, Indonesia's post-pandemic learning recovery requires scalable, evidence-based interventions that can be implemented with limited resources. Second, the Merdeka Curriculum (Independent Curriculum) introduced in 2022 explicitly encourages project-based and problem-based learning but provides limited guidance on gamification integration. Third, the rapid adoption of digital learning platforms in Indonesian schools creates an opportunity to embed gamification elements at low cost. Without empirical evidence on the effectiveness of gamification-PBL integration, teachers may invest time and resources in approaches that are not optimized for the Indonesian context.

The novelty of this study lies in four aspects. First, it is the first quasi-experimental study in Indonesia that fully integrates gamification elements (points, badges, levels, leaderboards, quests) across all five stages of the PBL syntax (problem orientation, organization and investigation, solution development, presentation, and reflection). Second, the study uses a comprehensive set of outcome measures including multiple motivation indicators (attention, perseverance, resilience, satisfaction, goal orientation) rather than a single composite score. Third, the study calculates effect sizes (Cohen's $d = 5.13$) that allow comparison with international benchmarks. Fourth, the study includes qualitative data from interviews and observations to explain the mechanisms underlying the quantitative findings.

The integration of gamification with PBL is expected to produce positive synergies in mathematics learning. Gamification provides a reward and competition structure that increases extrinsic motivation, while PBL builds intrinsic motivation through meaningful problem-solving. The combination of these two approaches has not been widely researched in the context of mathematics learning in Indonesia, so this research is important to be conducted.

Based on the background that has been described, the formulation of the problem in this study is: How is the application of the gamification approach integrated with PBL in mathematics learning?, How does the integration of gamification and PBL affect students' learning motivation in mathematics learning? How did the increase in motivation to learn differ between the group that used gamification-PBL integration and the group that used conventional learning? What are the challenges and solutions in implementing gamification and PBL in mathematics learning?

The objectives of this study are: Describe the application of gamification approaches integrated with PBL in mathematics learning. Analyze the influence of gamification and PBL integration on students' learning motivation in mathematics learning. To analyze the difference in increased learning motivation between the group that used gamification-PBL integration and the group that used conventional learning. Identify challenges and solutions in implementing gamification and PBL in mathematics learning.

RESEARCH METHODS

Research Design

This study uses a quasi-experimental method with a pretest-posttest control group design. The design of the study can be described as follows: Experimental Group: O_1 X O_2 Control Group: O_1 - O_2

Description:

a. O_1 = Pretest (measurement of learning motivation and early ability)
b. O_2 = Posttest (measurement of learning motivation and final ability)
c. X = Treatment in the form of learning with gamification-PBL integration
d. (-) = Conventional learning

Research Subject

Population: All students of class X of SMA Negeri 1 Kedungwaringin for the 2024/2025 school year totaling 180 students

Samples: Selected using purposive sampling techniques:

a. Class X-1 as an experimental group (30 students)
b. Class X-2 as a control group (30 students) Total research sample is 60 students

Research Instruments

1. Mathematics Learning Motivation Questionnaire
    a. Consists of 30 statements on a Likert scale of 1-5
    b. Content validation by 3 experts
    c. Cronbach's Alpha Reliability = 0.89
2. Mathematical Problem-Solving Ability Test
    a. 5 description questions based on the stages of Polya
    b. Expert-validated and tested
3. Observation Sheet
    a. Observation of student activities and learning implementation
4. Interview Guidelines
    b. Semi-structured interview for 10 students

Research Procedure

Stage 1: Preparation

a. Analysis of student needs and characteristics
b. PBL-integrated gamification learning design
c. Development of learning materials and media
d. Validation of research instruments

Stage 2: Implementation (8 weeks, 16 meetings)

GAMIFICATION-PBL DESIGN:

A. Gamification Elements:
1. Points: Awarded for each stage of PBL
    a. Problem orientation: 10 points
    b. Research: 20 points
    c. Solution development: 40 points

d. Presentation: 20 points
e. Reflection: 10 points
f. Creativity bonus: 10-20 points

2. Achievement Badge:
   a. "First Solver": The first group to complete
   b. "Creative Mind": The most creative/innovative solution
   c. "Team Champion": The best collaboration
   d. "Persistent Learner": Not giving up even when it's hard
   e. "Perfect Solution": A perfect solution without mistakes
   f. "Best Presenter": Best presentation
3. System Level:
   a. Level 1 (Beginner): 0-100 points
   b. Level 2 (Intermediate): 101-200 points
   c. Level 3 (Advanced): 201-300 points
   d. Level 4 (Expert): 301-400 points
   e. Level 5 (Master): >400 points
4. Leaderboard: Update after each session
5. Quest/Mission: Problems packed in an interesting narrative

B. Learning Syntax:
   Stage 1: Problem Orientation (Gamified)
      a. Students are awarded "Quest" or "Mission"
      b. Example: "Electronic Store Dilemma" - playing the role of a financial consultant
      c. Motivation points: 10 points for active engagement
   Stage 2: Organization and Investigation (Gamified)
      a. Groups of 4-5 people (in-game teams)
      b. Progress points: 20 points for problem identification
      c. Strategy points: 30 points for solution planning
   Stage 3: Solution Development (Gamified)
      a. Execution points: 40 points for correct solutions
      b. Bonus points: 10-20 for creativity
      c. Badge: "Problem Solver", "Creative Thinker", "Team Player"
   Stage 4: Presentation and Evaluation (Gamified)
      a. Presentation points: 20 points
      b. Peer review: 5 points per constructive feedback
      c. Leaderboard update
   Stage 5: Reflection (Gamified)
      a. Reflection points: 10 points
      b. Level up based on points accumulation
   Control Group: Conventional learning (expository)
   Stage 3: Posttest and Data Collection

Data Analysis Techniques

1. Descriptive Statistical Analysis
   a. Mean, median, mode, standard deviation
   b. Categorization of motivation levels

2. Prerequisite Test
   a. Normality test: Kolmogorov-Smirnov
   b. Homogeneity test: Levene's test
3. Hypothesis Test
   a. Paired t-test: Improvement in the group
   b. Independent t-test: Differences between groups
   c. N-Gain: The magnitude of the increase
   d. Effect size: Cohen's d
4. Qualitative Analysis
   a. Thematic analysis for interview data
   b. Descriptive analysis for observation

RESULTS AND DISCUSSION

Initial Capability Equivalence Test

Table 1. Initial Capability Equivalency Test Results

Variable	Groups	N	Red	SD	t	Sig.	Conclusion
UH Value	Experiments	30	72,50	8,45	0,324	0,747	Equivalent
	Controls	30	71,83	9,12	-	-	-
Pretest Motivation	Experiments	30	78,23	10,56	0,198	0,844	Equivalent
	Controls	30	77,67	11,23	-	-	-

Source: Primary Data (processed by researchers)

The results showed no significant difference (sig. > 0.05) between the two groups.

Descriptive Statistics of Learning Motivation

Table 2. Descriptive Statistics of Motivation to Learn Mathematics

Groups	Test	N	Min	Max	Red	SD	Categories
Experiments	**Pretest**	**30**	**62**	**98**	**78,23**	**10,56**	**Medium**
	Posttest	**30**	**85**	**138**	**115,47**	**12,34**	**Height**
Controls	**Pretest**	**30**	**60**	**97**	**77,67**	**11,23**	**Medium**
	Posttest	**30**	**68**	**105**	**86,33**	**10,78**	**Medium**

The experimental group experienced an increase of 37.24 points (from medium to high). The control group only increased by 8.66 points (remaining in the medium category).

Table 3. Distribution of Learning Motivation Categories

Categories	Pretest Experiment		Posttest Experiment		Pretest Control		Posttest Control	
	N	%	N	%	N	%	N	%
Very High	0	0,0	12	40,0	0	0,0	0	0,0
Height	8	26,7	16	53,3	7	23,3	11	36,7
Medium	20	66,7	2	6,7	21	70,0	17	56,7
Low	2	6,6	0	0,0	2	6,7	2	6,6

Source: Primary Data (processed by researchers)

40% of experimental students reach the very high category on the posttest.

Analysis Prerequisites Test

Table 4. Normality Test Results (Kolmogorov-Smirnov)

Data	Groups	Statistic	Sig.	Conclusion
Pretest	Experiments	0,112	0,200	**Normal**
	Controls	0,124	0,185	**Normal**
Posttest	Experiments	0,098	0,200	**Normal**
	Controls	0,106	0,200	**Normal**
N-Gain	Experiments	0,114	0,200	**Normal**
	Controls	0,131	0,152	**Normal**

Source: Primary Data (processed by researchers)

All data are normally distributed (sig. > 0.05).

Table 5. Homogeneity Test Results (Levene's Test)

Pretest	**0,124**	**0,726**	Homogeneous
Posttest	0,892	0,349	**Homogeneous**
N-Gain	0,456	0,502	**Homogeneous**

Source: Primary Data (processed by researchers)

All data were homogeneous (sig. > 0.05). The analysis can use parametric tests.

Motivation Enhancement Test in the Group

Table 6. Paired Sample T-Test Results

Groups	Red Pretest	Mean Posttest	Difference	t	df	Sig.	Conclusion
Experiments	78,23	115,47	**37,24**	18,456	29	0,000	**Significant**
Controls	77,67	86,33	**8,66**	4,782	29	0,000	**Significant**

Source: Primary Data (processed by researchers)

Both groups experienced significant improvements, but the experiments were much larger.

Test of Difference in Improvement between Groups

Table 7. Calculation of N-Gain Learning Motivation

Groups	N	Red N-Gain	SD N-Gain	Min	Max	Categories
Experiments	30	**0,68**	0,12	0,45	0,89	**Medium**
Controls	30	**0,15**	0,08	0,02	0,32	**Low**

Source: Primary Data (processed by researchers)

Table 8. Independent Sample T-Test Results on N-Gain

Variable	Groups	Red	SD	t	df	Sig.	Cohen's d
N-Gain Motivation	Experiments	0,68	0,12	**19,847**	58	**0,000**	**5,13**
	Controls	0,15	0,08	-	-	-	-

Source: Primary Data (processed by researchers)

The difference was very significant (p < 0.05) with a very large effect size (d = 5.13).

Analysis Per Motivation Indicator

Table 9. Increased Motivation Per Indicator

Indicator	Experiments			Controls		
	Pre	Post	Gain	Pre	Post	Gain
Attention/Interest	15,6	23,4	**7,8**	15,4	17,2	**1,8**
Perseverance	16,2	24,1	**7,9**	16,0	17,8	**1,8**
Durability	14,8	22,3	**7,5**	14,6	16,1	**1,5**
Satisfaction	15,9	23,7	**7,8**	15,8	17,5	**1,7**
Destination Orientation	15,7	22,0	**6,3**	15,9	17,7	**1,8**
TOTAL	**78,2**	**115,5**	**37,3**	**77,7**	**86,3**	**8,6**

Source: Primary Data (processed by researchers)

All indicators experienced significant improvements in the experimental group. Highest improvements: Perseverance (7.9) and Attention-Attraction (7.8).

Results of Qualitative Analysis (Observation & Interview)

Themes that emerged from qualitative data analysis:

1. LEARNING IS MORE INTERESTING AND FUN "Usually math is boring, but with this point and badge system, it's exciting. That's how it plays the game." (Student A)
2. GAMIFICATION ELEMENTS INCREASE MOTIVATION "Points and badges make us want to keep learning. Especially if you look at our leaderboard, our position is down, immediately enthusiastic again." (Student B)
3. PBL HELPS TO UNDERSTAND CONCEPTS MORE DEEPLY "If we learn from real problems, we understand why we should study SPLTV. It turns out that it is useful for daily life." (Student D)
4. COLLABORATION INCREASES "Group work becomes more fun because there is a common target. We have to work together to get a lot of points." (Student I)
5. IMPLEMENTATION CHALLENGES "Sometimes there is less time for discussion, especially when the problem is difficult." (Student C) "The leaderboard sometimes creates pressure as well, but overall it's still exciting." (Student B)

Effectiveness of Gamification-PBL Integration

The results showed that the integration of gamification with PBL significantly increased students' motivation to learn mathematics. This increase can be seen from a very significant difference ($p < 0.05$) with a very large effect size (Cohen's d = 5.13). The experimental group experienced an average increase in motivation of 37.24 points with an N-Gain of 0.68 (medium category), much higher than the control group which only increased by 8.66 points with an N-Gain of 0.15 (low category).

This effectiveness can be explained through several mechanisms:

A. SYNERGY OF EXTRINSIC AND INTRINSIC MOTIVATION

Gamification provides extrinsic motivation through a reward system (points, badges, levels) that provide direct feedback and recognition for students' efforts. This reward system triggers the release of dopamine in the brain which creates feelings of pleasure and wanting to continue engaging in the activity.

On the other hand, PBL builds intrinsic motivation through meaningful and real-life problem-solving, which makes students feel that learning mathematics has clear value and purpose. The combination of these two types of motivation creates a strong synergy.

This is in line with research that shows that problem-based gamification activities are more effective than non-problem-based activities due to the combination of the challenge of problem-solving and the engagement of gamification.

B. INCREASED ENGAGEMENT AND ACTIVE PARTICIPATION

Gamification elements such as quests, challenges, and leaderboards create more engaging and interactive learning situations. Students are no longer passively receiving information but actively engaging in the "game" of learning. The results of the observation showed that the students in the experimental group looked more excited, enthusiastic, and not bored during learning.

These findings are consistent with the research of Hui and Mahmud (2023) who found that the implementation of digital game-based learning can capture students' attention, motivate them to engage in learning, and increase their achievement rates.

C. IMMEDIATE FEEDBACK AND SENSE OF PROGRESS

The points and level system in gamification provides direct feedback to students on their performance and progress. This feedback helps students understand where they are currently and what needs to be done to progress further. This sense of progress is important to maintain motivation because students can see the concrete results of their efforts.

D. MEANINGFUL COLLABORATION

The integration of gamification with PBL creates more meaningful collaboration within the group. Team points and team badges encourage students to work together effectively because individual success is linked to group success. PBL provides a context for collaboration through shared problem-solving, while gamification provides a reward structure that makes collaboration more engaging.

E. DEEPER UNDERSTANDING OF CONCEPTS

PBL helps students understand mathematical concepts more deeply through contextual problem-solving. Students not only memorize formulas but understand how and when to apply mathematical concepts in real-life situations. Gamification supports this process by providing additional motivation to solve problems well.

Analysis Per Motivation Indicator

Significant improvements occurred in all aspects of motivation to learn mathematics:

1. PERSEVERANCE (Gain: 7.9 points) - HIGHEST The gamification system encourages students to be more diligent in doing math tasks. Target points and levels provide continuous motivation to keep trying.
2. ATTENTION AND INTEREST (Gain: 7.8 points) Gamification manages to grab students' attention and make them more interested in learning math. Quests and challenges create curiosity and excitement.
3. SATISFACTION (Gain: 7.8 points) Students enjoy the mathematics learning process more. Gamification creates a fun and rewarding experience, while PBL provides satisfaction from successfully solving meaningful problems.

4. RESILIENCE (Gain: 7.5 points) Students become more resilient in facing mathematical difficulties. The "Persistent Learner" badge recognizes students' efforts that do not give up.
5. GOAL ORIENTATION (Gain: 6.3 points) The level system and target points provide clear short-term goals, while contextual problem-solving provides an understanding of the long-term goals of studying mathematics.

Implementation Challenges and Solutions

CHALLENGE 1: Learning Time Management takes longer, especially in the early phases when students are still adapting.

SOLUTION:

a. Careful learning planning with realistic time allocation
b. Use of structured LKPD to guide student investigations
c. Provide clear time limits with visible timers
d. Students will become more efficient over time

CHALLENGE 2: Technology Readiness Not all schools have adequate technology infrastructure.

SOLUTION:

a. Low-tech gamification approach: manual scoreboards, physical badges
b. Use of a simple technology that is already available: projectors
c. Combination of digital and manual as per resource availability

CHALLENGE 3: Student Adaptation Some students need time to adapt to the new system.

SOLUTION:

a. Clear and detailed explanation of gamification systems
b. Strong scaffolding at the initial meeting
c. Intensive mentoring for students with difficulties
d. Providing concrete examples of how to earn points and badges

CHALLENGE 4: Competition-Collaboration Balance The leaderboard can create pressure for the group in the bottom position.

SOLUTION:

a. Emphasis on improvement from absolute ranking
b. Multiple leaderboards: individual, group, improvement, creativity
c. A points system that rewards effort and participation
d. Creating a supportive classroom culture

Research Implications

THEORETICAL IMPLICATIONS:

1. Strengthening Self-Determination Theory on the importance of autonomy, competence, and relatedness
2. Supporting the theory of constructivism in mathematics learning
3. Shows that extrinsic and intrinsic motivations can work synergistically

PRACTICAL IMPLICATIONS:

1. Teachers can adopt gamification-PBL integration to increase student motivation
2. Schools need to provide training and supporting infrastructure

3. Curriculum developers can include this approach in the guideline

CONCLUSION

The application of the gamification approach integrated with PBL is carried out by combining the syntax of PBL—starting from problem orientation, organization and investigation, solution development, presentation, to reflection—with gamification elements such as points, badges, levels, leaderboards, and quests or challenges. Math problems are packaged in the form of interesting and contextual quests, so that each stage of PBL not only demands collaborative problem-solving, but also provides a challenging and enjoyable learning experience. Each stage completion is rewarded with specific points and achievements, while student progress is visualized through a level system and leaderboard to increase a sense of progress and active engagement.

The integration of gamification with PBL has been shown to have a significant effect on increasing motivation to learn mathematics. The experimental group experienced an average increase in motivation of 37.24 points (from 78.23 to 115.47) with an N-Gain value of 0.68 (medium category), and the results of the paired t-test showed a significant improvement ($t = 18.456$; $p = 0.000 < 0.05$). There was also a very significant difference compared to the control group, with the results of the independent t-test on the N-Gain data of $t = 19.847$ and $p = 0.000 < 0.05$, as well as a very large effect size (Cohen's $d = 5.13$). Although its implementation faces challenges such as time management, technology readiness, student adaptation, and competition-collaboration balance, solutions can be done through careful planning, low-tech gamification approaches, scaffolding in the early phases, multiple leaderboards, and a variety of gamification elements. The effectiveness of this integration is also supported by the synergy of extrinsic and intrinsic motivation, increased engagement, direct feedback, meaningful collaboration, and deepening of concept understanding. The suggestions that can be given include encouragement for teachers to adapt approaches according to the context and continue to improve competence, school support through training and infrastructure, development of broader and in-depth follow-up research, and education policies that encourage the integration of gamification-PBL in curriculum and teacher training on a sustainable basis.

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