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DEEP LEARNING-BASED GAMIFICATION AND SELF-CONFIDENCE IN ENHANCING STUDENTS' MATHEMATICAL COMMUNICATION ABILITY

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ABSTRACT

This study aims to examine the effect of a deep learning-based gamification model on students' mathematical communication ability by considering their self-confidence. A quasi-experimental design was applied to seventh-grade students at SMP Negeri 4 Surakarta in the 2025/2026 academic year. The samples consisted of two experimental classes and one control class selected through cluster random sampling. Data were collected through pretests, posttests, self-confidence questionnaires, and documentation, and analyzed using a 3×3 two-way ANOVA with unequal cell sizes. The results showed that the learning model significantly affected students' mathematical communication ability, with an F-value of 3.168 and a p-value of 0.047. The deep learning-based gamification group obtained the highest mean score of 70.13, followed by gamification at 67.75 and direct instruction at 61.50. Self-confidence also significantly affected students' mathematical communication ability, with an F-value of 12.387 and a p-value below 0.001. No significant interaction was found between the learning model and self-confidence, with an F-value of 1.784 and a p-value of 0.139. These findings suggest that deep learning-based gamification has the potential to promote students' mathematical communication ability by engaging them in contextual challenges, explaining mathematical strategies, comparing solution representations, and reflecting on their reasoning, while self-confidence remains an important consideration in mathematics learning.

Keywords: Gamification, Deep Learning, Self-confidence, Mathematical Communication Ability.

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PRELIMINARY

Education plays a strategic role in developing human resources. Mathematics is taught at all levels of formal education because it contributes to the development of systematic and critical thinking (Ikhsan et al., 2020). Beyond mastering calculation procedures, mathematics also requires students to communicate mathematical ideas and reasoning through various representations, including tables, diagrams, and symbols (Fa et al., 2024). This ability is consistent with the objectives of mathematics education outlined in the Ministry of Education

and Culture's Mathematics Subject Guidelines, which emphasize students' ability to communicate mathematical ideas through appropriate representations.

Mathematical communication ability is essential for students to express ideas, clarify mathematical understanding, and evaluate mathematical arguments. Epih (2024) describes this ability as involving the expression and interpretation of mathematical ideas through analytical and critical reflection. Similarly, the National Council of Teachers of Mathematics (NCTM, as cited in Wahid & Marlina, 2022) identifies communication as both a means of conveying mathematical ideas and an indicator of conceptual understanding. However, Indonesian students' mathematics performance remains a concern. The Programme for International Student Assessment (PISA) 2022 reported that more than 70% of Indonesian students performed below the minimum proficiency level, with a mathematics score of 379 and a ranking of 68th (OECD, 2023). This concern is also reflected in the findings of Tina et al. (2025), who reported that only 16.6% of students demonstrated high mathematical communication ability, while 55.5% were in the low category.

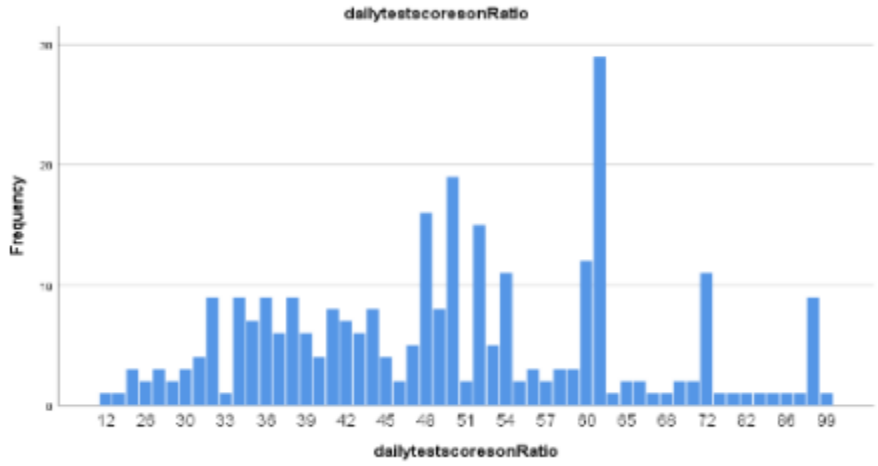


Figure 1. Daily Test Scores for Grade VII on Ratios at SMP Negeri 4 Surakarta in the 2024/2025 Academic Year

A preliminary study involving Grade VII students at SMP Negeri 4 Surakarta also indicated difficulties in learning ratios. The average daily test score was 50.74, with a median of 50 (Figure 1). Interviews with mathematics teachers further revealed that students tended to be passive and had difficulty explaining their problem-solving procedures, particularly when working on ratio problems. Similar difficulties have been reported by Aminatun (2023), who found that students struggled to understand proportional ratios and distinguish the procedures for solving different types of ratio problems. Dimyati and Maya (2023) also reported that Grade VII students had difficulty distinguishing direct and inverse comparisons. These findings

indicate that students may experience difficulties in understanding ratio concepts and communicating their mathematical reasoning.

Self-confidence is an important factor associated with students' mathematical communication ability, as students with higher self-confidence tend to demonstrate better communication skills (Lubis & Rahayu, 2023; Tina et al., 2025). However, lecture- and textbook-oriented instruction may limit opportunities for students to engage with mathematical concepts and apply them in various contexts (Widiastuti et al., 2025). Therefore, learning approaches that promote active participation and mathematical expression are needed. Deep learning, within the 2025 curriculum context, emphasizes conceptual understanding over memorization and encourages critical, creative, and communicative thinking. When integrated with gamification elements such as points, levels, and challenges, it can promote participation, collaboration, and enthusiasm for mathematics learning (Satriawan & Abdullah, 2025; Shofiyah & Anwar, 2024). Its principles of mindful, meaningful, and joyful learning further encourage students to explore meaning, connect ideas, and apply mathematical concepts through discussion, problem-solving, and feedback (Anisa et al., 2026; Siregar et al., 2025; Salma & Wijayanti, 2026; Jack et al., 2024). These experiences may strengthen students' self-confidence in expressing mathematical ideas and support their ability to explain reasoning and communicate solutions using mathematical representations (Widya et al., 2025).

Although previous studies have examined gamification, deep learning, and self-confidence in mathematics education, further empirical investigation is needed into their combined relevance to mathematical communication ability. In particular, few studies have compared deep learning-based gamification with gamification and direct learning while considering students' self-confidence. Therefore, this study aims to examine differences in students' mathematical communication ability across these three learning models, investigate differences based on students' levels of self-confidence, and determine whether an interaction exists between the learning model and self-confidence.

METHODS

This study employed a quantitative approach with a 3×3 factorial quasi-experimental design to examine differences in students' mathematical communication ability based on learning model and self-confidence level (high, medium, and low). The population comprised 264 seventh-grade students at SMP Negeri 4 Surakarta in the 2025/2026 academic year, distributed across eight classes. Using cluster random sampling, three classes of 32 students each were selected: class VII F as experimental class 1, receiving the deep learning-based

gamification learning model; class VII C as experimental class 2, receiving the gamification learning model; and class VII G as the control class, receiving the direct learning model. All groups studied the same mathematics topic and learning objectives, while their instructional activities and characteristics differed according to the assigned learning model, as summarized in Table 1.

Table 1. Learning Treatment in Each Group

Aspect	Deep Learning-Based Gamification	Gamification	Direct Learning
Main Syntax	1. Breaking down learning materials into levels 2. Integrating learning that is mindful, meaningful, and joyful 3. Contextual challenges and missions 4. Deep collaboration and reflection 5. Conceptual and metacognitive evaluation (Wijaya, 2020)	1. Setting learning objectives 2. Designing game activities 3. Implementing gamification 4. Evaluation and reflection (Sainjakit, 2025)	1. Orientation to learning objectives 2. Presentation of materials 3. Structured practice 4. Guided practice 5. Independent practice (Huda, 2017)
Learning Activities	Learning activities combine gamification elements with mindful, meaningful, and joyful learning through contextual problems, challenges, collaboration, reflection, and feedback.	Learning activities incorporate game elements such as challenges, levels, points, rewards, interaction, and time-based activities.	Learning activities emphasize teacher explanation, worked examples, guided practice, and independent exercises.
Main Characteristics	Interactive, reflective, contextual, collaborative, and meaning-oriented.	Interactive, competitive, and enjoyable.	Teacher-directed, structured, and controlled.

In the deep learning-based gamification group, game activities incorporated mindful, meaningful, and joyful learning principles, whereas the gamification group used game elements to support students' participation and interaction without explicitly integrating these principles. The direct learning group, in contrast, followed teacher-directed activities without gamification. Data were collected through tests and non-test methods. The test instrument was an open-ended essay test measuring mathematical communication ability, consisting of five questions with 11 sub-items in the pretest and seven in the posttest. The items were developed based on three indicators adapted from Rosdianti et al. (2020): written text, drawing, and mathematical

expression. The test was administered before and after the treatment and validated through expert judgment by three validators: one mathematics education lecturer and two mathematics teachers. They assessed the alignment of the items with the mathematical communication indicators, the clarity of instructions and language, and their suitability for seventh-grade students. Revisions were made based on their feedback before the test items were administered.

Table 2. Test Question Grid

No	Indicators of Competence Achievement	Mathematical Communication Indicators	Cognitive Dimension
1	Students can explain the concept of ratios, various forms of ratios, and their use in everyday life	1. Students can write down what they know and what they are asked about in a math problem (Written Text).	C3 (Apply)
2	Students are able to distinguish between differences, which are comparisons by addition, and ratios, which are comparisons by multiplication.	2. Students can explain or express mathematical problems clearly in the form of pictures or tables (Drawing).	C3 (Apply)
3	Students are able to use scale factors to solve problems related to ratios.	3. Students can express mathematical ideas in mathematical models of given problems and can develop strategies to solve given problems (Mathematical Expression).	C4 (Analyze)
4	Students are able to relate equivalent ratios to proportions in solving everyday problems.		C4 (Analyze)
5	Students can use ratios (and related rates of change) to solve problems.		C4 (Analyze)

Based on Table 2, students' responses to the mathematical communication ability test were scored using a predetermined scoring rubric. The rubric assessed students' ability to communicate mathematical ideas through written text, visual representations, and mathematical expressions. Each response was evaluated based on the accuracy, completeness, and clarity of the mathematical information and representation provided. The item analysis included discrimination and difficulty indices. All pretest and posttest items met the predetermined discrimination criterion of $D \geq 0.30$. Items with difficulty indices between 0.30 and 0.70 were considered acceptable. After item selection, the reliability coefficient was 0.868 for the pretest and 0.719 for the posttest, indicating that both instruments met the reliability criterion of $r_{11} \geq 0.30$.

The non-test instrument questionnaires were used to measure students' self-confidence levels during the learning process using a four-point Likert scale (Budiyono, 2017; Sugiyono, 2015, p. 142). The questionnaire is used to classify students into high, medium, and low self-confidence categories based on the criteria score in the following Table 3.

Table 3. Self-confidence Criteria Score

Criteria	Interval	Interval Score
High	$X \geq \bar{X} + \frac{1}{2}\, s$	$X \geq 64.7$
Medium	$\bar{X} - \frac{1}{2}\, s \leq X < \bar{X} + \frac{1}{2}\, s$	$60.7 \leq X \leq 64.7$
Low	$X < \bar{X} - \frac{1}{2}\, s$	$X < 60.7$

Students' self-confidence was classified into high, medium, and low categories based on four indicators adapted from Muqopi and Afriansyah (2025): belief in one's abilities, independence in decision-making, positive self-perception, and courage in expressing opinions. The questionnaire underwent content validation by two experts in guidance and counseling, resulting in 25 valid items from the initial 26, with a reliability coefficient of 0.872, exceeding the minimum criterion of 0.70. Data were analyzed using two-way ANOVA with unequal cell counts, preceded by normality, homogeneity, and balance tests to ensure statistical assumptions and group equivalence (Budiyono, 2018, p. 60). Multiple comparison tests were subsequently conducted when significant differences were identified.

RESULT AND DISCUSSION

1. Results of Descriptive Data

The results of the pretest and posttest data analysis for class VII F using a deep learning-based gamification learning model showed a significant increase in mathematical communication ability in the subject of Ratios.

Table 4. Descriptive Statistics of Pretest and Posttest Scores for Experimental Class 1 (VII F)

Statistics	Pretest	Posttest
Number of Students	32	32
Maximum Value	86	96
Minimum Value	32	50
Mean	54.69	70.13
Standard Deviation	16.7303	15.9773

The test Description of pretest and posttest scores for experimental class 1 (VII F) is presented in Table 4. Based on the data, it shows an average increase of 15.44, which is equivalent to an increase of about 15% from the initial score.

Table 5. Descriptive Statistics of Posttest Scores Based on Self-Confidence in Experimental Class 1

Self-confidence	Sample Size	Mean
High	12	81.58
Medium	11	70.73
Low	9	54.11

The results show that students with high self-confidence obtained the highest mean score, followed by those with medium and low self-confidence. This pattern indicates descriptive differences in mathematical communication ability across self-confidence categories within the deep learning-based gamification group.

Table 6. Descriptive Statistics of Pretest and Posttest Scores for Experimental Class 2 (VII C)

Statistics	Pretest	Posttest
Sample Size	32	32
Maximum Value	86	96
Minimum Value	30	43
Mean	54.83	67.75
Standard Deviation	15.6264	16.0870

The test Description of pretest and posttest scores for experimental class 2 (VII C) is presented in Table 6. The results of the pretest and posttest data analysis for class VII C using the gamification learning model showed a significant increase in mathematical communication ability in the subject of Ratios. Based on the data, it shows an average increase of 12.92, which is equivalent to an increase of about 12% from the initial score.

Table 7. Descriptive Statistics of Posttest Scores Based on Self-Confidence in Experimental Class 2

Self-confidence	Sample Size	Mean
High	10	71.10
Medium	10	67.70
Low	12	64.92

The mean scores indicate that students with high self-confidence obtained the highest score, followed by those with medium and low self-confidence. However, the differences among the three categories were descriptively smaller than those observed in the deep learning-based gamification group.

Table 8. Descriptive Statistics of Pretest and Posttest Scores for Control Class (VII G)

Statistics	Pretest	Posttest
Sample Size	32	32
Maximum Value	84	89
Minimum Value	16	29
Mean	53.41	61.50

Statistics	Pretest	Posttest
Standard Deviation	18.1635	16.3219

The test Description of pretest and posttest scores for the control class (VII G) is presented in Table 8. The results of the pretest and posttest data analysis for class VII G using the direct learning model showed a significant increase in mathematical communication ability in the subject of Ratios. Based on the data, it shows an average increase of 8.09, which is equivalent to an increase of about 8% from the initial score.

Table 9. Descriptive Statistics of Posttest Scores Based on Self-Confidence in Control Class (VII G)

Self-confidence	Sample Size	Mean
High	12	67.17
Medium	11	66.00
Low	9	48.44

In the direct learning group, students with high and medium self-confidence obtained relatively similar mean scores, while those with low self-confidence achieved lower scores, indicating differences in mathematical communication ability across self-confidence categories. The data were analyzed using two-way ANOVA with adjustments for unequal cell counts, preceded by normality and homogeneity tests to ensure that the data met the required statistical assumptions.

2. Normality Test

The normality test was conducted using the Lilliefors test to determine whether the pretest and posttest data were normally distributed. The results of the analysis are presented in the following table:

Table 10. Normality Test of Pretest Data (*Liliefors Test)*

Class	n	L_{obs}	L_{table}	Conclusion
Experimental Class 1	32	.102521	.1542	Normal
Experimental Class 2	32	.149978	.1542	Normal
Control Class	32	.095637	.1542	Normal

Table 10 shows that the observed L values (Lobs) for the three groups were lower than the critical L value (Ltable) at $\alpha = 0.05$. Therefore, the null hypothesis was not rejected, indicating that the pretest data were normally distributed.

Table 11. Normality Test of Posttest Data (*Lilliefors Test)*

Class	n	L_{obs}	L_{table}	Conclusion
Experimental Class 1	32	.149272	.1542	Normal
Experimental Class 2	32	.117007	.1542	Normal
Control Class	32	.103061	.1542	Normal
High	34	.068449	.1497	Normal
Medium	32	.108877	.1542	Normal
Low	30	.130565	.1590	Normal

Table 11 shows that the observed L values (Lobs) for the three groups were lower than the critical L value (Ltable) at α = 0.05. Therefore, the null hypothesis was not rejected, indicating that the posttest data were normally distributed.

3. Homogeneity Test

The homogeneity test was conducted to determine whether the variances of the groups were homogeneous. The results of the analysis using the Chi-square Test are presented in the following table:

Table 12. Result of the Homogeneity Pretest Data (*Chi-square Test)*

Class	n	L_{obs}	L_{table}	Conclusion
Experimental Class 1	32	.102521	.1542	Homogeneous
Experimental Class 2	32	.149978	.1542	Homogeneous
Control Class	32	.095637	.1542	Homogeneous

Table 12 shows that the observed value was lower than the critical Chi-square value at α = 0.05. Therefore, the null hypothesis was not rejected, indicating that the variances among the pretest data were homogeneous.

Table 13. Results of the Homogeneity of Posttest Data (*Chi-square Test)*

Variable	χ^2_{obs}	χ^2_{table}	Conclusion
Learning Model	.01906	5.991465	Homogeneous
Self-confidence	2.98227	5.991465	Homogeneous

Table 13 shows that the observed value was lower than the critical Chi-square value at α = 0.05. Therefore, the null hypothesis was not rejected, indicating that the variances among the posttest data were homogeneous.

Before the treatment, a one-way ANOVA was conducted to check the initial equality of the three groups based on pretest scores. The results showed that Fobs = 0.06986 was lower than Ftable = 3.094 at α = 0.05. So, the null hypothesis was not rejected, which means there was no significant difference in initial mathematical communication ability among the three groups.

4. Results of Hypothesis Testing

From the test results, it is known that the sample comes from a population that is normally distributed with homogeneous variance. With these analysis requirements fulfilled, the data testing is then continued using two-way ANOVA.

Based on Table 14 of the two-way analysis of variance (ANOVA) for unequal cells, the learning model significantly affected students' mathematical communication ability ($F(2, 87) = 3.168$, $p = 0.047 < 0.05$). This indicates that students' mathematical

communication ability differed significantly among the deep learning-based gamification, gamification, and direct learning groups. Self-confidence also had a significant effect on students' mathematical communication ability ($F(2, 87) = 12.387$, $p < 0.001$), indicating significant differences among students with high, medium, and low self-confidence. The results of the two-way analysis of variance (ANOVA) are presented in Table 14.

Table 14. The Results of The Two-Way Analysis of Variance (ANOVA)

Source	Sum of Squares	df	Mean Square	F_{obs}	F_{table}	p-value
Learning Model (Factor A)	1301.51	2	650.7532	3.16752	3.10130	.047
Self-confidence (Factor B)	5089.89	2	2544.4459	12.38741	3.10130	.001
Interaction (AB)	1465.87	4	366.4687	1.78377	2.47649	.139
Error	17873.79	87	205.4459			
Total	25731.06	95				

However, the interaction between the learning model and self-confidence was not significant ($F(4, 87) = 1.784$, $p = 0.139 > 0.05$). Thus, the effect of the learning model did not significantly differ across self-confidence categories.

Since significant differences were found for the learning model and self-confidence, a post hoc analysis was conducted to identify which groups differed significantly. The results of the post hoc analysis are presented in the following table:

Table 15. Results of Scheffé Post Hoc Test

Factor	Pairwise Comparison	F_{obs}	F_{table}	Conclusion
Learning Model (Factor A)	Experiment 1 vs. Experiment 2	12.4510	6.20259	Significant difference
	Experiment 1 vs. Control	8.1820	6.20259	Significant difference
	Experiment 2 vs. Control	7.5868	6.20259	Significant difference
Self-confidence (Factor B)	High vs. Medium	24.21625	6.20259	Significant difference
	High vs. Low	21.23545	6.20259	Significant difference
	Medium vs. Low	9.60590	6.20259	Significant difference

Table 12 shows that the results of the Scheffé post hoc test of the three learning models differed significantly from one another. The deep learning-based gamification group

differed significantly from both the gamification and direct learning groups, while the gamification group also differed significantly from the direct learning group. The results also show significant differences among all self-confidence categories. Based on the marginal means, students with high self-confidence obtained the highest mean score (73.41), followed by students with medium self-confidence (68.16) and low self-confidence (56.87). Thus, the mathematical communication ability differed significantly across the high, medium, and low self-confidence categories.

5. Discussion

This result indicates that the learning model and self-confidence each had a significant main effect on students' mathematical communication ability in the topic of Ratios, while no significant interaction was found between the two factors.

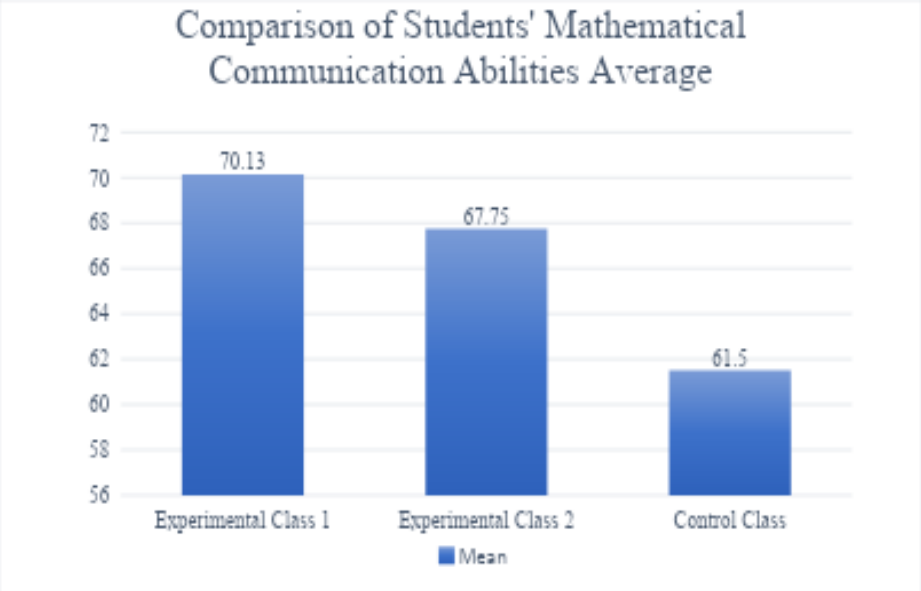


Figure 2. Comparison of Students' Mathematical Communication Abilities Average

As illustrated in Figure 2, the deep learning-based gamification group obtained the highest mean score (70.13), followed by the gamification group (67.75) and the direct learning group (61.50). The pretest analysis showed no significant difference in initial mathematical communication ability among the three groups ($F_{obs} = 0.070 < F_{table} = 3.094$, $\alpha = 0.05$). Thus, the groups were comparable at baseline, and posttest scores were used to examine differences after the learning treatments. From a constructivist perspective, the higher mean score in the deep learning-based gamification group reflects learning as an active process in which students construct knowledge by engaging with problems, learning experiences, and other learners. In this study, students participated in challenges, problem-solving activities, discussions, feedback, and reflection. These activities provided

opportunities to explore mathematical concepts, compare solution strategies, and explain their reasoning. The integration of mindful, meaningful, and joyful learning further encouraged students to connect mathematical concepts with contextual problems. Consequently, students were not only required to obtain correct answers but also to explain the processes and reasoning underlying their solutions. These learning experiences may help explain the higher mathematical communication mean observed in the deep learning-based gamification group.

This finding is consistent with Shofiyah and Anwar (2024), who reported that gamification can foster students' enthusiasm and motivation in mathematics learning. Satriawan and Abdullah (2025) also found that gamification can support interaction and confidence while developing critical thinking and mathematical communication. The present study extends these findings by integrating gamification elements with deep learning principles. While challenges, interaction, and rewards encourage active participation, mindful, meaningful, and joyful learning emphasize conceptual understanding and reflection. The combination may therefore provide opportunities for students to communicate mathematical ideas while developing a deeper understanding of the concepts being studied.

Self-confidence also had a significant main effect on students' mathematical communication ability. The marginal means showed that students with high self-confidence obtained the highest score (73.41), followed by those with medium self-confidence (68.16) and low self-confidence (56.87). The Scheffé test confirmed significant differences between all three categories. This finding highlights the relevance of self-confidence to students' willingness to express mathematical ideas, explain solution procedures, participate in discussions, and present mathematical representations. Lubis and Rahayu (2023) similarly reported that self-confidence contributes to the quality of students' mathematical communication. Students who are hesitant to express their ideas may have fewer opportunities to practice explaining their reasoning, whereas those with greater confidence may be more willing to communicate their mathematical thinking. These results suggest that attention to students' affective characteristics is important alongside the implementation of instructional models.

Although the learning model and self-confidence each had a significant main effect, their interaction was not significant. This means that the effect of the learning model did not differ significantly across self-confidence categories. Descriptively, the deep learning-based gamification group obtained higher mean scores among students with high and medium self-

confidence, whereas the gamification group obtained a higher mean among students with low self-confidence. However, this pattern should not be interpreted as evidence that a particular model is more effective for a specific self-confidence category because the interaction effect was not statistically significant.

The descriptive pattern among students with low self-confidence is also relevant when considered alongside the findings of Alt (2023), who reported that students with low self-confidence may not always be able to optimally utilize gamification strategies. In the present study, although the gamification group showed a higher mean than the deep learning-based gamification group among students with low self-confidence, the overall interaction effect was not significant. This suggests that the observed difference should not be interpreted as evidence that gamification is generally more suitable for students with low self-confidence. Instead, it may indicate that students with different levels of self-confidence can respond differently to particular learning activities, although such differences were not sufficiently consistent to produce a statistically significant interaction in this study.

Taken together, the findings support the view that gamification and deep learning can provide complementary learning experiences. Gamification provides challenges, interaction, and motivational elements that can encourage students to participate actively, as reported by Shofiyah & Anwar (2024) and Satriawan & Abdullah (2025). Meanwhile, the deep learning emphasizes meaningful understanding and encourages students to connect concepts, reason about solutions, and reflect on their learning. From a constructivist perspective, these activities provide opportunities for students to actively construct mathematical knowledge and communicate their understanding. At the same time, the significant differences across self-confidence levels indicate that students' affective characteristics remain relevant to their ability to express mathematical ideas. Therefore, the findings suggest that improving mathematical communication ability requires not only innovative learning activities but also classroom conditions that encourage students to participate, explain their reasoning, and develop self-confidence in communicating mathematical ideas.

From a pedagogical perspective, teachers can combine interactive gamification activities with learning tasks that require students to explain concepts, justify solution strategies, and reflect on their reasoning. For students with lower self-confidence, teachers may provide gradual scaffolding, opportunities for small-group discussion, and a supportive environment in which students can express ideas without fear of making mistakes. Such support may help students participate more actively in mathematical communication ability.

CONCLUSION

Based on the findings of this study, it can be concluded that the learning model significantly affected students' mathematical communication ability. The deep learning-based gamification group obtained the highest mean score (70.13), followed by the gamification group (67.75) and the direct learning group (61.50), with significant differences among the three learning models. Self-confidence also had a significant effect on mathematical communication ability, with mean scores of 73.41, 68.16, and 56.87 for students with high, medium, and low self-confidence, respectively. The significant differences among self-confidence categories indicate that self-confidence is an important factor in students' mathematical communication ability. However, the interaction between the learning model and self-confidence was not significant, indicating that the effect of the learning model did not differ significantly across self-confidence levels.

In practice, deep learning-based gamification can be implemented through contextual challenges, reflective activities, opportunities to explain and compare solution strategies, and constructive feedback to support students' mathematical communication. Students with lower self-confidence may also benefit from gradual scaffolding and supportive opportunities to express mathematical ideas. This study was limited to 96 seventh-grade students from one school and one mathematics topic. Further research should examine the model across different mathematics topics, grade levels, and school contexts with larger samples, as well as investigate specific gamification elements that may contribute to students' mathematical communication ability.

DECLARATIONS

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