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THE EFFECT OF PROBLEM-BASED LEARNING ASSISTED BY FUN MATH QUEST BASED ON QR CODE ON THE COMPUTATIONAL THINKING AND MATHEMATICAL REASONING SKILLS OF ELEMENTARY SCHOOL STUDENTS

Pebri Yanti[1*], Heris Hendriana[2], Muhammad Ghiyats Ristiana[3]
[1,2,3]IKIP Siliwangi,
[1]pebriyanti779@gmail.com

Abstract

The low computational thinking and mathematical reasoning skills of students in fractions material indicate the need for more interactive and meaningful learning innovations. This study aims to analyze the effect of Problem-Based Learning assisted by Fun Math Quest based on QR Code on computational thinking and mathematical reasoning skills of elementary school students. This study used a mixed method with an explanatory sequential design. The research subjects consisted of 60 fourth-grade elementary school students selected using a purposive sampling technique. The research instruments included computational thinking and mathematical reasoning skills tests, student response questionnaires, interviews, and observations. Quantitative data were analyzed using N-gain, Independent Sample t-test, and effect size (Cohen's d), while qualitative data were analyzed descriptively to explain the quantitative results. The results showed that the experimental class obtained an increase in computational thinking skills (N-gain = 0.56) and mathematical reasoning skills (N-gain = 0.53) with a moderate category, while the control class obtained N-gains of 0.31 and 0.37, respectively. The results of the Independent Sample t-test showed that the computational thinking and mathematical reasoning skills of students in the experimental class were significantly higher than those of the control class. Effect size analysis showed a very large effect on computational thinking skills (d = 2.14) and a large effect on mathematical reasoning skills (d = 1.26). Qualitative data showed that the use of QR Code-based Fun Math Quest increased student engagement, supported systematic problem solving, and helped develop computational thinking and mathematical reasoning skills. In addition, student responses to learning were in the good category with an average of 75%. The conclusion of the study showed that Problem-Based Learning assisted by QR Code-based Fun Math Quest had a positive effect on elementary school students' computational thinking and mathematical reasoning skills and supported the creation of active, collaborative, and meaningful learning.

Keywords: *Problem-Based Learning; gamification; Fun Math Quest; computational thinking; mathematical reasoning*

Abstrak

Rendahnya kemampuan berpikir komputasional dan penalaran matematis siswa pada materi pecahan menunjukkan perlunya inovasi pembelajaran yang lebih interaktif dan bermakna. Penelitian ini bertujuan menganalisis pengaruh Problem Based Learning berbantuan Fun Math Quest berbasis QR Code terhadap kemampuan berpikir komputasional dan penalaran matematis siswa sekolah dasar. Penelitian ini menggunakan pendekatan mixed methods dengan desain explanatory sequential. Subjek penelitian terdiri atas 60 siswa kelas IV sekolah dasar yang dipilih menggunakan teknik purposive sampling. Instrumen penelitian meliputi tes kemampuan berpikir komputasional dan penalaran matematis, angket respons siswa, wawancara, dan observasi. Data kuantitatif dianalisis menggunakan N-gain, Independent Sample t-test, dan effect size (Cohen's d), sedangkan data kualitatif dianalisis secara deskriptif untuk menjelaskan hasil kuantitatif. Hasil penelitian menunjukkan bahwa kelas eksperimen memperoleh peningkatan kemampuan berpikir komputasional (N-gain = 0,56) dan penalaran matematis (N-gain = 0,53) dengan kategori sedang, sedangkan kelas kontrol memperoleh N-gain masing-masing sebesar 0,31 dan 0,37. Hasil uji Independent Sample t-test menunjukkan bahwa kemampuan berpikir komputasional dan penalaran matematis siswa pada kelas eksperimen secara signifikan lebih tinggi dibandingkan kelas kontrol. Hasil analisis effect size menunjukkan bahwa pembelajaran memberikan pengaruh yang sangat besar terhadap kemampuan berpikir komputasional (d = 2,14) dan pengaruh yang besar terhadap kemampuan penalaran matematis (d = 1,26). Data kualitatif menunjukkan bahwa penggunaan Fun Math Quest berbasis QR Code meningkatkan keterlibatan siswa, mendukung pemecahan masalah secara sistematis, serta membantu pengembangan kemampuan berpikir komputasional dan penalaran matematis. Selain itu, respons siswa terhadap pembelajaran berada pada kategori baik dengan rata-rata 75%. Simpulan penelitian menunjukkan bahwa Problem Based Learning berbantuan Fun Math Quest berbasis QR Code berpengaruh positif terhadap kemampuan berpikir komputasional dan penalaran matematis siswa sekolah dasar serta mendukung terciptanya pembelajaran yang aktif, kolaboratif, dan bermakna.

Kata Kunci: Problem Based Learning; gamifikasi; Fun Math Quest; berpikir komputasional; penalaran matematis

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Introduction

The development of education in the 21st century requires students to possess advanced thinking skills to effectively solve problems. Computational thinking and mathematical reasoning are essential skills in today's education. Computational thinking encompasses the ability to solve problems logically, systematically, and structuredly through problem-solving, pattern recognition, abstraction, and algorithm development (Supiarmo et al., 2021). These skills are considered crucial competencies that must be cultivated from elementary school because they support students in facing various challenges in the digital era (Tang et al., 2020). Irawati & Hadi (2025) also emphasize that strengthening computational thinking skills from elementary school can improve problem-solving and logical decision-making skills.

In addition to computational thinking skills, mathematical reasoning skills are one of the main targets in mathematics education. Mathematical thinking supports students in making predictions, providing logical arguments, evaluating statements, and drawing conclusions based on the mathematical concepts they have learned (Akuba et al., 2020). This ability plays a crucial role in building deep understanding, so that students not only remember the solution procedures but also understand the basis of each step (Jeannotte & Kieran, 2017). Therefore, the development of computational thinking and mathematical reasoning skills must be carried out simultaneously through learning methods that provide students with opportunities to explore, analyze, and actively solve problems.

Advances in digital technology have driven a transformation in mathematics teaching methods, making them more creative and interactive (Hayati et al., 2023). The use of technology in mathematics learning is considered to improve the quality of the learning experience for elementary school students (Firmansyah et al., 2025). However, evaluations at both the national and international levels indicate that Indonesian students' mathematical abilities remain low, particularly in logic and problem-solving (Jusniati et al., 2024). Students' low mathematical thinking skills are also influenced by teaching methods that are still dominated by teachers and provide little space for students to develop their own knowledge (Wanelly & Fatmawati, 2020). This situation indicates the need for innovation in learning methods that can be more effective in improving students' higher-order thinking skills (Prayoga & Setyaningsih, 2021).

Mathematics learning at the elementary school level still faces various challenges, particularly related to fractions. Interviews with teachers revealed that even though learning is supported by the use of real-world media and contextual methods, students still face difficulties in comparing fractions, simplifying fractions, and relating fraction concepts to everyday life. These obstacles contribute to students' low learning achievement in fractions. This finding aligns with research conducted by Gampu et al. (2025), which showed that fractions remain a difficult topic for elementary school students to understand. A contextual and meaningful learning approach is needed to help students gain a deeper understanding of fraction concepts (Nopitry et al., 2025).

Theoretically, this study is based on the principle of constructivism, which assumes that knowledge is actively acquired by students through learning experiences and interactions with the surrounding environment (Piaget & Inhelder, 1972). Vygotsky (1978) stated that students' cognitive development can be enhanced through social engagement and support during the learning process. Referring to the concept of constructivism, learning must be designed in such a way that students can be actively involved in constructing knowledge through exploration, discussion, and problem-solving activities. From a constructivist perspective, learning will be more meaningful when students actively participate in creating knowledge through direct experience, social interaction, and problem-solving. In this study, Problem-Based Learning serves as an approach that facilitates knowledge formation through solving real problems, while the gamification of Fun Math Quest aims to increase student engagement and motivation to learn. QR Code is implemented as a scaffolding tool that helps students obtain information and instructions gradually during the problem-solving process. The combination of these three elements is expected to support the development of computational thinking skills and mathematical reasoning students more optimally.

One learning approach that aligns with constructivist principles is Problem-Based Learning (PBL). In the PBL model, real-world problems serve as the starting point for the learning process, encouraging students to develop knowledge through investigation and problem-solving (Alhayat et al., 2023). PBL encourages students to engage in conversations, seek alternative solutions, and independently develop conceptual understanding (Handayani & Koeswanti, 2021). Previous research has shown that PBL is effective in improving students' critical thinking skills, problem-solving abilities, and higher-order thinking skills (Negara et al., 2023). Furthermore, PBL also supports the development of computational thinking skills because students are taught to analyze challenges and design structured solution strategies (Pérez-Escolar et al., 2021).

The effectiveness of problem-based learning in mathematics learning can be further enhanced through the integration of gamification. Gamification refers to the use of game elements in a learning context to increase student motivation and engagement (Bernal Párraga et al., 2024). Various studies have shown that the implementation of gamification contributes to increased student participation during the mathematics learning process (Wijayanti & Yanto, 2023). In line with these findings, Ratinho et al. (2026) suggested that the use of gamification can increase student engagement in various mathematics learning activities. The results of a meta-analysis conducted by Sailer & Homner (2020) also showed that gamification has a positive effect on learning motivation, student engagement, and learning outcomes. In addition to supporting motivational aspects, gamification can provide a more challenging and engaging learning experience, encouraging students to actively participate in completing various learning tasks (Nurningtias & Mustadi, 2022).

Advances in digital technology provide various opportunities to develop more interactive learning media, one of which is through the use of Quick Response Codes (QR Codes). This technology allows students to quickly access materials, instructions, and learning activities through digital devices (Kandiri et al., 2025). Several studies have shown that the use of QR Codes can increase student engagement and foster curiosity during the learning process (Rosdianwinata et al., 2022). Agustang et al. (2021) stated that QR Codes play a role in increasing learning interactivity while supporting student learning independence. These findings are supported by Makur et al. (2021), who demonstrated that QR Code-based learning environments can encourage student participation in learning activities utilizing technology. In this study, QR Codes were used as digital scaffolding that provided information and step-by-step instructions to help students complete various math challenges in the Fun Math Quest media.

Computational thinking skills are an essential competency students need to develop for 21st-century learning. In mathematics, these skills help students identify and analyze problems, recognize patterns, abstract important information, and develop logical and systematic solution procedures (Maharani, 2020). Several studies have shown that QR Code-based educational games can support the development of computational thinking skills in elementary school students (Al Husaeni et al., 2023). Interactive digital learning media have also been reported to improve students' thinking skills in learning mathematical concepts (Pramasdyahsari et al., 2023).

Mathematical reasoning skills, alongside computational thinking skills, play a crucial role in helping students understand relationships between mathematical concepts and develop reasoning to support their solutions. This ability is a fundamental aspect of mathematics learning because it enables students to develop conjectures, present logical arguments, and draw justifiable conclusions (NCTM, 2000). Previous research has shown that the application of Problem-Based Learning supported by digital media positively contributes to improving students' mathematical reasoning skills (Kusaeri et al., 2022). Furthermore, the use of interactive learning media has also been reported to support the development of logical thinking skills and strengthen students' understanding of mathematical concepts (Hui & Mahmud, 2023).

Various previous studies have demonstrated that Problem-Based Learning is effective in developing students' higher-order thinking skills. Research by Negara et al. (2023) demonstrated that Problem-Based Learning can improve students' critical thinking and problem-solving skills. Meanwhile, research by Sailer and Homner (2020) revealed that gamification has a positive impact on learning motivation, student engagement, and learning outcomes. Research by Rosdianwinata et al. (2022) and Palupi et al. (2022) also demonstrated that QR Codes are effectively used as interactive learning media that can increase student engagement during the learning process. However, most of these studies still examine Problem-Based Learning, gamification, and QR Codes separately. Research that integrates these three components into a single learning design to simultaneously develop computational thinking and mathematical reasoning skills in elementary school students is still relatively limited. Furthermore, research specifically applying QR Code-based Fun Math Quest media to fractions to improve these two skills is also still rare. This condition indicates a research gap related to the integration of Problem-Based Learning, gamification, and QR Code in developing computational thinking and mathematical reasoning skills simultaneously in elementary school students, which still requires further study.

The novelty of this research lies in the integration of the Problem-Based Learning model, Fun Math Quest gamification, and QR Code technology into a single learning design developed to simultaneously improve elementary school students' computational thinking and mathematical reasoning skills. Unlike previous studies that generally examined these three components separately, this study examines the contribution of their integration in mathematics learning on fractions in elementary schools. Furthermore, this study applies a mixed methods approach with an explanatory sequential design that allows for quantitative measurement of learning effects while providing explanations of the learning process and student responses based on qualitative data.

Based on the theoretical foundation and previous research findings, this study hypothesizes that the Problem-Based Learning model, supported by the QR Code-based Fun Math Quest gamification, has a positive impact on elementary school students' computational thinking and mathematical reasoning skills. Based on the background and studies described above, this study aims to analyze the effect of implementing the Problem-Based Learning model, supported by the QR Code-based Fun Math Quest gamification, on elementary school students' computational thinking and mathematical reasoning skills.

Research Methods

This study employed a mixed methods approach with a sequential explanatory design. This design combines quantitative and qualitative methods sequentially, with quantitative data collection and analysis initially followed by qualitative data collection and analysis to explain and strengthen the quantitative findings (Creswell & Clark, 2017). In the quantitative phase, the study employed a quasi-experimental method with a nonequivalent control group design.

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X	O_2
Control	O_3	–	O_4

Description:
O_1 = Pretest for experimental class
O_2 = Posttest for experimental class
O_3 = Pretest for control class
O_4 = Posttest for control class
X = Problem-Based Learning with the help of QR Code-based Fun Math Quest

The study was conducted at a public elementary school in Cimahi City in the even semester of the 2025/2026 academic year. The study sample consisted of 60 fourth-grade students selected using a purposive sampling technique. The sample consisted of 30 fourth-grade students in grade IV-A as the experimental class who received Problem-Based Learning learning assisted by QR Code-based Fun Math Quest gamification, and 30 fourth-grade students in grade IV-B as the control class who received conventional learning. The selection of the two classes was based on the similarity of academic characteristics, material studied, previous learning outcomes, and class teacher recommendations, so that both groups were considered to have relatively equal initial conditions. In addition, one class teacher was involved as an informant in qualitative data collection.

Data collection techniques were conducted through tests and non-tests. The test instrument consisted of 10 descriptive questions used to measure students' computational thinking and mathematical reasoning skills. The non-test instruments consisted of observation sheets on learning implementation, student response questionnaires, and semi-structured interviews with teachers.

Before being used in the study, the instrument was piloted on students with similar characteristics to the research sample. The results of the empirical validity test showed that all items had validity coefficients between 0.471 and 0.767, thus meeting the validity criteria. The results of the reliability test using Cronbach's Alpha obtained a coefficient of 0.878, indicating that the instrument has high reliability (Taber, 2018). Based on the results of the validity, reliability, discriminating power, and difficulty level analysis, 10 items were selected as suitable for use as a research instrument.

Computational thinking skills were measured based on four aspects, namely decomposition, pattern recognition, abstraction, and algorithmic thinking (Wing, 2006). Meanwhile, mathematical reasoning skills were measured through indicators of proposing conjectures, providing mathematical justification, drawing conclusions, and checking the validity of arguments (Jeannotte & Kieran, 2017). The instrument grid for computational thinking and mathematical reasoning skills is presented in Table 2, while the student response questionnaire grid is presented in Table 3.

Quantitative data analysis was conducted to determine the improvement and differences in students' computational thinking and mathematical reasoning skills after the treatment was given. The improvement in students' abilities was analyzed using the N-gain score. Furthermore, the differences in computational thinking and mathematical reasoning skills between the experimental and control classes were analyzed using the Independent Sample t-test at a significance level of 0.05. Effect size was calculated using Cohen's d based on the posttest scores of the experimental and control groups. The calculation used the difference between the group means divided by the pooled standard deviation. To determine the magnitude of the treatment effect, an effect size analysis (Cohen's d) was conducted, which was interpreted based on the categories of small (0.20), medium (0.50), and large (0.80) (Cohen, 1988). All quantitative data analysis was conducted using IBM SPSS Statistics software version 26.

The research data was analyzed in stages to provide more systematic and in-depth results. Quantitative and qualitative data were combined to gain a more comprehensive understanding of the application of the QR code-based Fun Math Quest gamification-assisted Problem-Based Learning model in elementary school mathematics learning (Hafriani, 2021).

Table 2. Computational Thinking and Mathematical Reasoning Skills Test Grid

Variable	Indicator	Form of Ability
Computational Thinking	Decomposition	Breaking down mixed fraction problems into simpler forms
	Pattern Recognition	Finding relationships and regularities between fraction data
	Abstraction	Simplifying important information and ignoring irrelevant information
	Algorithmic Thinking	Organizing solution steps systematically and logically
Mathematical Reasoning	Making Conjectures	Making predictions about possible answers based on patterns or data
	Mathematical Justification	Providing logical and justifiable mathematical reasons
	Drawing Conclusions	Drawing conclusions based on the process used
	Evaluating the Validity of Arguments	Evaluating the correctness of results and proving equality or inequality

Table 3. Student Response Questionnaire Grid

Indicator	Statement Number	Number of Items
Demonstrating a preference for the Problem-Based Learning model	1,2,3,4,5,6,7,8,9,10	10
Student activities in groups	11,12,13,14,15,16,17,18,19,20	10
Benefits of computational thinking and mathematical reasoning skills	21,22,23,24,25,26,27,28,29,30	10

Analysis of student responses to learning was carried out by giving a score to each statement using a Likert scale, namely strongly agree (4), agree (3), disagree (2), and strongly disagree (1). The percentage of student responses was calculated using the following formula.

$$V = \frac{f}{N} x\ 100\%$$

Description:

V : Percentage
f : Score obtained
N : Maximum Score

Classification of interpretations of student responses to Problem-Based Learning is as follows:

Table 4. Criteria for student responses to learning

Score Interval	Student Response Category
$0-20\%$	Very Poor
$21-40\%$	Poor
$41-60\%$	Fairly Good
$61-80\%$	Good
$81-100\%$	Very Good

The interviews in this study used a semi-structured technique with questions aimed at exploring students' mathematical problem-solving abilities. The interviews were conducted to obtain additional, in-depth data related to the results of the students' computational thinking and mathematical reasoning tests.

Qualitative data obtained through observation and interviews were analyzed using the interactive model of Miles, Huberman, and Saldaña, which includes data reduction, data presentation, and conclusion drawing (Miles et al., 2014). Observation data were used to describe the implementation of the QR Code-based Fun Math Quest gamification-assisted Problem-Based Learning syntax during the learning process, while interview data were used to explain teachers' perceptions of the influence of learning on students' computational thinking and mathematical reasoning skills.

The explanatory sequential research procedure was carried out in four stages, namely: (1) implementing a pretest in the experimental class and the control class to determine students' initial abilities; (2) providing treatment in the form of Problem Based Learning assisted by Fun Math Quest gamification based on QR Code in the experimental class and conventional learning in the control class; (3) implementing a posttest and analyzing quantitative data using

N-gain, Independent Sample t-test, and effect size (Cohen's d); and (4) collecting and analyzing qualitative data through observation and interviews to explain the quantitative findings obtained.

Data integration was conducted at the interpretation stage by connecting quantitative and qualitative findings. The results of learning implementation observations and teacher interviews were used to explain the improvement in students' computational thinking and mathematical reasoning skills obtained through quantitative analysis, thereby obtaining a more comprehensive understanding of the effectiveness of Problem-Based Learning assisted by QR Code-based Fun Math Quest gamification in elementary school mathematics learning.

Results and Discussion

The results of the quantitative research include analysis of the improvement of computational thinking and mathematical reasoning skills using N-gain, testing the differences in skills between the experimental class and the control class using the Independent Sample t-test, and effect size analysis to determine the magnitude of the treatment's influence.

Table 5. Summary of N-gain Results

Variable	Experiment	Category	Control	Category
Computational Thinking	0.56	Medium	0.31	Medium
Mathematical Reasoning	0.53	Medium	0.37	Medium

Description:

$g > 0{,}7$ = High

$0.3 \leq g \leq 0{,}7$ = Medium

$g < 0{,}3$ = Low

Based on Table 5, the computational thinking skills of students in the experimental class obtained an N-gain value of 0.56, while the control class obtained an N-gain value of 0.31. In mathematical reasoning skills, the experimental class obtained an N-gain value of 0.53, while the control class obtained an N-gain value of 0.37. These results indicate that the increase in computational thinking and mathematical reasoning skills of students in the experimental class was higher than in the control class.

To determine the differences in students' abilities after the treatment was given, an Independent Sample t-test was conducted.

Table 6. Results of the Independent Sample t-test

Variable	Experimental Mean	Control Mean	t	Sig.
Computational Thinking	78.33	49.17	8.309	0.000
Mathematical Reasoning	72.83	56.33	4.896	0.000

The results of the Independent Sample t-test showed that there was a significant difference between the experimental class and the control class in computational thinking skills ($t = 8.309$; $p < 0.05$). The average score of students' computational thinking skills in the experimental class ($M = 78.33$) was higher than that of the control class ($M = 49.17$). In addition, there was a significant difference in mathematical reasoning skills between the experimental class and the control class ($t = 4.896$; $p < 0.05$). The average score of students' mathematical reasoning in the experimental class ($M = 72.83$) was higher than that of the control class ($M = 56.33$). These findings indicate that the implementation of Problem-Based Learning assisted by Fun Math Quest based on QR Code has a positive influence on the computational thinking and mathematical reasoning skills of elementary school students.

Table 7. Effect Size Test Results (Cohen's d)

Variable	Cohen's d	Interpretation
Computational Thinking	2.14	Very Large
Mathematical Reasoning	1.26	Large

Based on the results of the effect size calculation using Cohen's d, computational thinking skills obtained a d value of 2.14, which is categorized as very large. Meanwhile, mathematical reasoning skills obtained a d value of 1.26, which is categorized as large. These results indicate that the implementation of Problem-Based Learning assisted by Fun Math Quest, based on QR Code, not only produces statistically significant differences but also has a strong influence on improving computational thinking and mathematical reasoning skills of elementary school students. The large effect size value indicates that the influence of learning has a strong practical meaning in improving both abilities. These findings indicate that the integration of Problem-Based Learning, Fun Math Quest gamification, and QR Code provides a substantial contribution to the quality of mathematics learning in elementary schools.

The improvement in computational thinking skills in the experimental class can be explained through the characteristics of Problem-Based Learning assisted by Fun Math Quest gamification based on QR Code. During the learning process, students engaged in activities such as identifying problems, scanning QR Codes for clues, discussing solution strategies, and systematically organizing solution steps. These activities directly trained the skills of decomposition, pattern recognition, abstraction, and algorithmic thinking, which are the main components of computational thinking. These findings indicate that the improvement in computational thinking skills was not only due to the use of QR Code technology, but also because students were actively involved in a structured problem-solving process.

These findings align with constructivist theory, which states that knowledge is actively constructed through learning experiences and social interactions. Through Problem-Based Learning (PBL) supported by the QR Code-based Fun Math Quest, students have the opportunity to explore problems, discuss them, build understanding, and develop independent problem-solving strategies. This process allows students to construct knowledge more meaningfully, thus optimally developing computational thinking skills.

The improvement in mathematical reasoning skills in the experimental class demonstrated that students were not only able to obtain correct answers but also to provide mathematical reasoning, evaluate arguments, and draw logical conclusions. Throughout the learning process, students were faced with various challenges that required them to discuss solution strategies, justify their answers, and verify the accuracy of their results.

The results of this study also align with Sulistyanto et al. (2022), who stated that learning that requires students to solve problems based on Higher Order Thinking Skills (HOTS) can improve mathematical reasoning skills. Research by Ariati & Juandi (2022) also shows that mathematical reasoning skills develop through problem-solving experiences accompanied by gradual scaffolding. Furthermore, Rosdianwinata et al. (2022) explain that the use of QR Codes in mathematics learning can help students understand concepts more logically and systematically. The characteristic of Fun Math Quest, which requires students to complete challenges in stages, prevents students from proceeding to the next stage without understanding the mathematical reasoning for the answers obtained. This process encourages students to justify, check the validity of arguments, and draw conclusions based on mathematical evidence, thus optimally developing mathematical reasoning skills.

The results of this study align with those of Jeannotte & Kieran (2017), who explained that mathematical reasoning develops through activities such as making conjectures, providing justification, evaluating arguments, and drawing logical conclusions. These findings are also supported by Agustang et al. (2021), who stated that the use of interactive technology in learning can increase student engagement in thinking and reasoning processes. Furthermore, Sailer & Homner (2020) explained that gamification can increase student motivation and engagement, thus improving higher-order thinking skills.

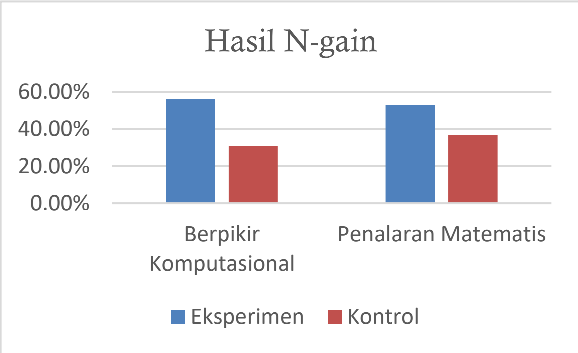


Figure 1. Comparison Diagram of N-gain of Experimental Class and Control Class

In addition to the test results, this study also analyzed students' responses to learning using the Problem-Based Learning model assisted by QR Code-based Fun Math Quest media.

Table 8.
Results of Student Responses to Problem Based Learning Assisted by Fun Math Quest

Indicators	Total Score	SMI	Percentage	Category
Demonstrating a preference for the Problem-Based Learning model	931	1200	78%	Good
Student activities in groups	914	1200	76%	Good
Benefits of computational thinking and mathematical reasoning skills	868	1200	72%	Good
Average			75%	Good

Based on Table 8, the average student response to the learning process reached 75%, categorized as good. The highest percentage was found in the indicator of liking the Problem-Based Learning model, at 78%. These results indicate that the integration of QR Code-based Fun Math Quest gamification can create a more engaging learning environment and increase student engagement during the learning process.

These findings are reinforced by observations showing that the entire syntax of Problem-Based Learning assisted by the QR Code-based Fun Math Quest gamification was implemented very well. Teachers consistently facilitated problem-solving activities, group discussions, QR Code-based explorations, and learning reflections. Interviews with teachers also showed that the Fun Math Quest media was able to increase student engagement, encourage computational thinking skills through systematic problem-solving, and develop mathematical reasoning because students had to understand and reason each solution before moving on to the next challenge.

These qualitative findings reinforce the quantitative results that showed an increase in computational thinking and mathematical reasoning skills in the experimental class. Thus, observation and interview data not only serve as a complement but also provide an explanation of the mechanism by which QR Code-based Problem-Based Learning (PBL) can improve students' computational thinking and mathematical reasoning skills. These observations and interview findings support the explanatory sequential design used in this study. The quantitative results indicate an increase in computational thinking and mathematical reasoning skills, while the qualitative results explain that this increase occurred because students were actively involved in the problem-solving process, group discussions, QR Code-based explorations, and learning reflections facilitated through the gamification of Fun Math Quest.

Presentation of interview results of high category students for computational thinking and mathematical reasoning skills

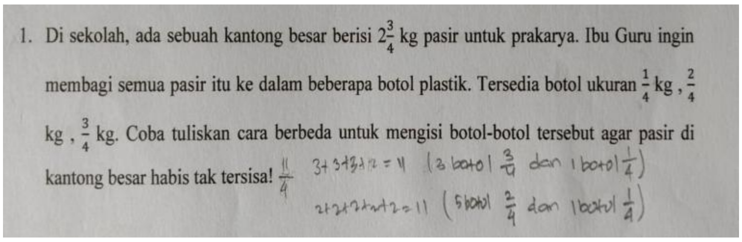

1. Di sekolah, ada sebuah kantong besar berisi $2\frac{3}{4}$ kg pasir untuk prakarya. Ibu Guru ingin membagi semua pasir itu ke dalam beberapa botol plastik. Tersedia botol ukuran $\frac{1}{4}$ kg , $\frac{2}{4}$ kg , $\frac{3}{4}$ kg. Coba tuliskan cara berbeda untuk mengisi botol-botol tersebut agar pasir di kantong besar habis tak tersisa! $\frac{11}{4}$ 3+3+3+2 = 11 (3 botol $\frac{3}{4}$ dan 1 botol $\frac{1}{4}$)
2+2+2+2+2+1 = 11 (5 botol $\frac{2}{4}$ dan 1 botol $\frac{1}{4}$)

Figure 2. Interview Results for High Computational thinking skills Category

PY : I see your answers are all correct. Here you wrote the number 11. May I know why you chose that number?

S1 : That's the number of the sand. $2\ \frac{3}{4}$ equals eleven quarters when counted. So i just took eleven to make it easier to divide among the bottles

PY : So how did you decide which bottle to use first?

S1 : I'll do it in order, ma'am. I used the largest bottle, $\frac{3}{4}$ then I counted three times to get nine, because I needed eleven, which meant two more. Then I used the $\frac{2}{4}$ bottle, so I used that to make it exactly eleven.

PY : Why are you so sure this method will completely use up all the sand?

S1 : Because when I added all the upper numbers (3+3+3+2), the result was exactly eleven.

PY : So why did you choose a different bottle in the second method?

S1 : Just to make it different, ma'am. I tried using the middle $\frac{2}{4}$ bottle, which had five, so I got ten. I was missing one more, so I added $\frac{1}{4}$ of the smallest bottle. The result was still 11.

Based on Figure 2, students in the high category were able to decompose problems, systematically organize solution steps, and find more than one alternative answer. This finding demonstrates mastery of the decomposition and algorithm aspects of computational thinking and aligns with the findings of (Shin et al., 2022).

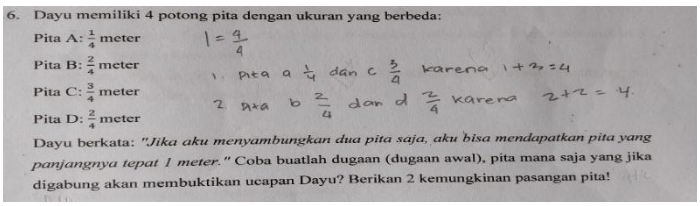

6. Dayu memiliki 4 potong pita dengan ukuran yang berbeda:
Pita A: $\frac{1}{4}$ meter
Pita B: $\frac{2}{4}$ meter
Pita C: $\frac{3}{4}$ meter
Pita D: $\frac{2}{4}$ meter
$1 = \frac{4}{4}$
1. pita a $\frac{1}{4}$ dan c $\frac{3}{4}$ karena 1+3=4
2 pita b $\frac{2}{4}$ dan d $\frac{2}{4}$ karena 2+2=4.
Dayu berkata: *"Jika aku menyambungkan dua pita saja, aku bisa mendapatkan pita yang panjangnya tepat 1 meter."* Coba buatlah dugaan (dugaan awal), pita mana saja yang jika digabung akan membuktikan ucapan Dayu? Berikan 2 kemungkinan pasangan pita!

Figure 3. Interview Results for the High Category of Mathematical reasoning skills

PY : I see you've found two pairs of ribbons that, when combined, make exactly 1 meter. Why did you choose Ribbon A and Ribbon C in your first choice?

S1 : Because Ribbon A is $\frac{3}{4}$ meter, and Ribbon C is $\frac{3}{4}$ meter. When you connect them, you add them. One plus three equals four, so the result is $\frac{4}{4}$. So, $\frac{4}{4}$ is the same as 1 meter, right?

PY : So for the second possibility, you wrote Ribbon B plus Ribbon B. Why did you choose Ribbon B twice? Is that allowed?

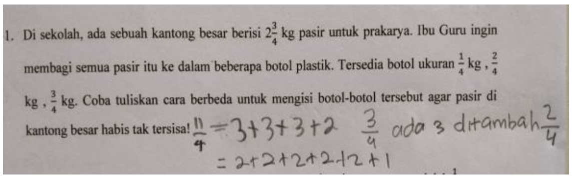
S1 : It's okay, right? The question doesn't say you can't use the same ribbon. Ribbon B is $\frac{2}{4}$, so if there are two, then two plus two equals four. The result is also $\frac{4}{4}$, so it's still 1 meter.

PY : How are you sure that $\frac{4}{4}$ equals 1 meter? Why not 4 meters?

S1 : "Per" means divided, right? Four divided by four equals one.

Based on Figure 3, high-ability students were able to provide logical mathematical justification and explain the relationship between the fraction 4/4 and 1 meter. Furthermore, they were able to identify more than one possible answer. This finding supports the research findings of Marzuki (2021) regarding the mathematical justification abilities of high-ability students.

Presentation of interview results of students in the medium category for computational thinking and mathematical reasoning skills



1. Di sekolah, ada sebuah kantong besar berisi $2\frac{3}{4}$ kg pasir untuk prakarya. Ibu Guru ingin membagi semua pasir itu ke dalam beberapa botol plastik. Tersedia botol ukuran $\frac{1}{4}$ kg , $\frac{2}{4}$ kg , $\frac{3}{4}$ kg. Coba tuliskan cara berbeda untuk mengisi botol-botol tersebut agar pasir di kantong besar habis tak tersisa! $\frac{11}{4} = 3+3+3+2$ $\frac{3}{4}$ ada 3 ditambah $\frac{2}{4}$

$= 2+2+2+2+2+1$

Figure 4. Interview Results for the Medium Computational thinking skills Category

PY : I see you've found a way to use up the sand. Can you explain why you wrote the number 11 there?

S2 : It's from the sand. 2 $\frac{3}{4}$, when converted into a fraction, is 11 over 4. So I looked for numbers that added up to 11.

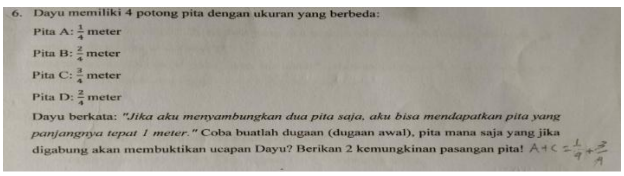
PY : So, how did you come up with the numbers 3, 3, 3, and 2?

S2 : I looked at the largest bottle first; it's $\frac{3}{4}$. I tried adding 3, adding 3 more to get 6, adding 3 more to get 9. Then, to get 11, I just added 2 more.

PY : Why didn't you write another way? The question asked for different ways.

S2 : I was having trouble thinking of other numbers that would equal 11, ma'am. I thought one way would be enough.

Based on Figure 4, students in the moderate category were able to solve problems using the correct procedures, but were still fixated on one solution strategy and unable to generate alternative answers independently. This finding aligns with (Ru et al., 2022).



6. Dayu memiliki 4 potong pita dengan ukuran yang berbeda:
Pita A: $\frac{1}{4}$ meter
Pita B: $\frac{2}{4}$ meter
Pita C: $\frac{3}{4}$ meter
Pita D: $\frac{2}{4}$ meter
Dayu berkata: *"Jika aku menyambungkan dua pita saja, aku bisa mendapatkan pita yang panjangnya tepat 1 meter."* Coba buatlah dugaan (dugaan awal), pita mana saja yang jika digabung akan membuktikan ucapan Dayu? Berikan 2 kemungkinan pasangan pita! $A+C = \frac{1}{4}+\frac{3}{4}$

Figure 5. Interview Results for the Moderate Category of Mathematical reasoning skills

PY : You wrote down the pairs of Ribbon A and Ribbon C to get a ribbon 1 meter long. Can you explain why you chose those two ribbons?

S2 : Because if you add them together, the result is exactly one, ma'am. Ribbon A is one-quarter, Ribbon C is three-quarters. One plus three equals four, making four-quarters. That equals one meter.

PY : The question asked for two possible ribbon pairs. Why did you only write one on the answer sheet?

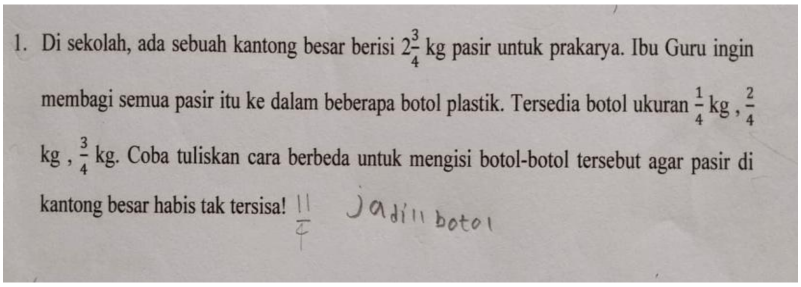
S2 : Yes, I'm only focusing on one ribbon.

PY : Look at Ribbon B, which measures $\frac{2}{4}$ meter. If you have two Ribbon Bs, can you make one meter?

S2 : Oh yes, you can. Two plus two equals four. That also equals 4/4. So you can use Ribbon B twice, right?

Based on Figure 5 and interview results, students in the moderate category were able to explain why a pair of ribbons produces 1 meter, but were still fixated on one answer combination and unable to explore other possibilities without guidance. These results align with research by Iswara et al. (2022) which explains that students in the moderate category lack flexibility in exploring alternative mathematical solutions.

Exposure to interview results of low category students for computational thinking and mathematical reasoning skills



1. Di sekolah, ada sebuah kantong besar berisi $2\frac{3}{4}$ kg pasir untuk prakarya. Ibu Guru ingin membagi semua pasir itu ke dalam beberapa botol plastik. Tersedia botol ukuran $\frac{1}{4}$ kg , $\frac{2}{4}$ kg , $\frac{3}{4}$ kg. Coba tuliskan cara berbeda untuk mengisi botol-botol tersebut agar pasir di kantong besar habis tak tersisa! $\frac{11}{4}$ Jadi 11 botol

Figure 6. Interview Results for the Low Computational thinking skills Category

PY : I see your answer only has the number 11 written on it. Can you tell me why you only wrote that number?

S3 : Yes, there's $2\frac{3}{4}$ of the sand, so if you count the tops, it's 11. So, 11 is the answer.

PY : Oh, so you think if you've found the number 11, that means the problem is over?

S3 : Yes, you've found the number. I thought 11 was the answer, so there was no need to count the bottles anymore.

PY : But the question asked the teacher to divide the sand into $\frac{3}{4}$, $\frac{2}{4}$, $\frac{1}{4}$ bottles. What do you think you're going to do with the number 11 in these bottles?

S3 : I'm confused about putting them back in the bottles. I only know I got the number 11.

Based on Figure 6 and interview results, low-skilled students were only able to convert mixed fractions into the number 11, but were unable to connect that number to the division process into the available bottles. They were also unable to systematically organize the solution steps. This finding aligns with research by Riyadi et al. (2021) which states that low-skilled students tend to focus solely on the final result without understanding the problem-solving process.

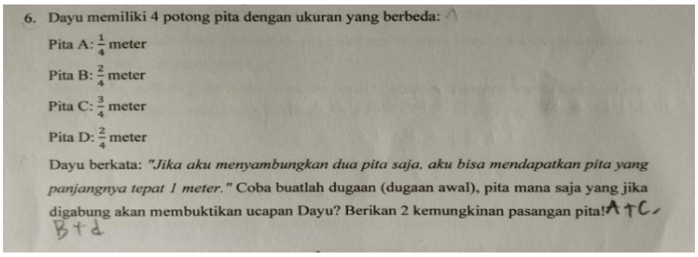

6. Dayu memiliki 4 potong pita dengan ukuran yang berbeda:
Pita A: $\frac{1}{4}$ meter
Pita B: $\frac{2}{4}$ meter
Pita C: $\frac{3}{4}$ meter
Pita D: $\frac{2}{4}$ meter
Dayu berkata: *"Jika aku menyambungkan dua pita saja, aku bisa mendapatkan pita yang panjangnya tepat 1 meter."* Coba buatlah dugaan (dugaan awal), pita mana saja yang jika digabung akan membuktikan ucapan Dayu? Berikan 2 kemungkinan pasangan pita! A+C,
B+d

Figure 7. Interview Results for the Low Mathematical reasoning skills Category

PY	:	I saw you chose Ribbon A and C, then Ribbon B and D. May I ask why you chose those pairs?
S3	:	It just fits, ma'am. I see the numbers it seems like they fit together.
PY	:	What do you mean by "fit"? Let's look at A and C. The numbers are $\frac{1}{4}$ and $\frac{3}{4}$, so what do they add up to?"
S3	:	So, four. One plus three is four.
PY	:	So, how many meters does four quarters equal?
S3	:	I don't know, ma'am. The main thing is that the numbers are the same at the top and bottom. I remember that if the numbers are the same, that's the answer.

Based on Figure 7, students in the low category were unable to provide accurate mathematical justification and still relied on intuition to determine their answers. They also did not understand the conceptual relationship between the fraction $\frac{4}{4}$ and 1 meter. This finding is supported by research by (Sihombing & Silalahi, 2021).

In general, the findings of this study indicate that the use of a Problem-Based Learning model equipped with QR Code-based Fun Math Quest gamification can support students in improving computational thinking and mathematical reasoning skills. This problem-focused learning method, accompanied by gamification elements, creates a more interactive, relevant, and enjoyable learning experience, so that students are better able to understand mathematical concepts and are more active in the process of solving problems independently.

The findings of this study reinforce the novelty proposed in the introduction, namely that the integration of Problem-Based Learning, Fun Math Quest gamification, and QR Codes can simultaneously develop computational thinking and mathematical reasoning skills. The results show that QR Codes function not only as a medium for accessing information but also as digital scaffolding that supports the problem-solving process in a Problem-Based Learning-based gamification environment.

Conclusion

Based on the research results, it can be concluded that the Problem-Based Learning model assisted by Fun Math Quest gamification based on QR Code has a positive effect on elementary school students' computational thinking and mathematical reasoning skills on fractions. The implementation of learning that integrates problem-solving activities, group discussions, gamification, and QR Code-based exploration is able to support students in developing computational thinking and mathematical reasoning skills more optimally. This finding strengthens the constructivist view that active student involvement in problem solving and meaningful learning interactions can support the development of higher-order thinking skills. This research provides an empirical contribution that the integration of Problem-Based Learning, gamification, and QR Code can be an innovative alternative in elementary school mathematics learning to support the development of students' computational thinking and mathematical reasoning skills.

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