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Torma Code Interactive Media: A Problem Based Learning Innovation to Enhance Critical Thingking Skills among Elementary School Students

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A B S T R A C T

The rapid development of learning technology requires teachers to use innovative media that encourage students' higher-order thinking skills. In elementary schools, science learning is still dominated by textbooks and teacher explanations, resulting in low student engagement and limited opportunities for developing critical thinking skills. Therefore, interactive media that supports inquiry and exploration is needed. This study aims to develop and evaluate the effectiveness of Torma Code, an interactive learning media based on the Problem Based Learning (PBL) model, in the Natural and Social Sciences (IPAS) subject on the topic of the sense of sight to enhance students' critical thinking skills. The research employed a Research and Development (R&D) approach using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The media, teaching module, and test instruments were validated by two experts and categorized as very valid with average feasibility scores exceeding 90%. Practicality testing involving teachers and students also resulted in a very practical category with scores above 92%. Effectiveness testing through a paired sample t-test showed a significant difference between pretest and posttest (Sig. < 0.05), while an N-Gain score of 0.55 indicated moderate improvement. Thus, Torma Code is valid, practical, and effective in improving critical thinking skills.

1. Introduction

The development of science and technology in the era of globalization has had a significant impact on various aspects of life, including education. Twenty-first-century education requires students to possess skills that are not only focused on cognitive aspects but also on higher-order thinking skills and the ability to adapt to the changing times (Relitawati et al., 2024). In this context, the concept of 21st Century Skills, also known as the 4Cs, refers to Critical Thinking, Collaboration, Communication, and Creativity. These four skills serve as a crucial foundation to prepare young generations capable of facing future challenges with critical, creative, and innovative thinking.

One of the primary skills that must be developed is critical thinking. Davidi et al. (2021) emphasized that critical thinking skills need to be integrated into the learning process in elementary schools as an effort to meet the demands of 21st-century education. According to Ennis in Syafitri et al. (2021), critical thinking is a reflective and logical thinking activity used to determine what is reasonable to believe or do. Meanwhile, Glaser in Novandi et al. (2025) explained that critical thinking is the ability to consider a problem deeply and objectively. Firdausi et al. (2021) further added that critical thinking skills are also related to the ability to solve complex problems in daily life. Therefore, critical thinking can be understood as an analytical, reflective, and rational ability that is essential for developing students' intellectual potential.

Previous studies indicate that the implementation of appropriate learning models can significantly influence the improvement of critical thinking skills. Novandi et al. (2025) demonstrated that the application of experimental, discussion-based, and interactive media learning strategies could enhance elementary students' critical thinking skills. Conversely, Amalia et al. (2021) found that students' critical thinking abilities were still relatively low, particularly in Science and Social Studies (IPAS), because the learning process remained conventional and did not actively involve students. A similar condition was found at SDN Watupecah, where initial assessments showed that students' critical thinking skills on the topic of the sense of vision were still low. According to interview results, teachers stated that IPAS learning still relied on lectures with limited media, which did not stimulate active student participation.

According to Hayati and Setiawan (2022), students' low critical thinking skills are influenced by several factors, including insufficient teacher preparedness in designing learning, minimal use of interactive media, and inadequate application of learning models that require students to think scientifically. Therefore, teachers need to develop innovative learning strategies and media to enable students to think actively and reflectively. One approach relevant to these needs is Problem-Based Learning (PBL). This model places students at the center of learning and challenges them to solve real problems through exploration and collaboration activities (Lestari & Gunawan, 2023; Purnama et al., 2024). In line with this, the use of interactive media in learning has proven effective in increasing student engagement and critical thinking skills. Handayani et al. (2022) showed that the use of digital and interactive media could enhance critical thinking abilities and learning motivation among elementary students. Mulyawati et al. (2024) emphasized that interactive media designed using Articulate Storyline could create meaningful and engaging learning experiences for students. Similar findings were reported by Cahyaningsih and Nahdi (2025), who developed a PBL-based interactive e-module, which proved effective in improving elementary students' critical thinking skills.

Based on these findings, the development of the Torma Code interactive media based on Problem-Based Learning is an appropriate solution to improve students' critical thinking skills in IPAS learning, particularly on the topic of the sense of vision. This topic is important because it is directly related to students' daily lives and has great potential for training scientific thinking and logical reasoning skills. The development of this interactive media is expected to make the learning process more engaging, meaningful, and capable of optimizing students' critical thinking skills.

2. Methodology

This study employed a Research and Development (R&D) methodology aimed at producing innovative and effective learning media tailored to the needs of elementary school students. According to Gay in Okpatrioka (2023), development research is a systematic activity directed toward designing and validating educational products that can be applied in real educational settings. Rangkuti (2016) emphasizes that development research is not only oriented toward theoretical reinforcement but also produces practical solutions to learning problems faced by teachers and students. Therefore, this study focused on developing Torma Code interactive media based on Problem-Based Learning (PBL), aimed at enhancing critical thinking skills among elementary school students.

The development model used in this study was the ADDIE model, consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation. This model was selected because it is systematic, flexible, and provides opportunities for continuous evaluation at each stage of development (Slamet, 2022). Each stage plays a crucial role in ensuring that the resulting product is not only content-valid but also practical and effective for classroom use. The study was conducted at SDN Watupecah and SDN Sumurpule in Semarang Regency. These schools were selected because they have relatively similar learning conditions, both in terms of resources and student characteristics. The research was carried out from July 2025 and continued until all stages of media development were completed. The research process followed the sequence of the ADDIE stages: needs analysis, product design, development, field implementation, and media effectiveness evaluation.

The first stage was Analysis, conducted to identify learning needs, students' initial abilities, and their characteristics. Needs analysis was carried out through observation, teacher interviews, and a pretest of students' critical thinking skills. The results indicated that IPAS learning on the sense of vision still relied on lectures and textbooks without adequate visual media support, making it difficult for students to understand abstract concepts and demonstrate critical thinking skills. Therefore, the development of interactive media capable of visualizing vision-related content and engaging students in scientific thinking was required. The second stage was Design, where the researchers designed Torma Code media, an interactive media system based on barcodes combined with eye torsos and mobile simulations.

This media allows students to scan codes to access learning content in the form of videos, images, and brief explanations. Components were arranged to align with elementary students' characteristics, who prefer exploratory and visual activities. The design stage also included the preparation of research instruments, such as expert validation sheets, practicality observation sheets, and critical thinking ability tests. The third stage was Development, which involved realizing the product design into a tangible form. The developed interactive media was then validated by two media and learning experts from Universitas PGRI Semarang. The validation aimed to assess the product's feasibility in terms of content accuracy, visual appearance, language, ease of use, and alignment with the PBL model. Validation

was conducted using a Likert-scale assessment sheet following the guidelines of Akbar in Slamet (2022). The fourth stage was Implementation, conducted through limited trials in Grade IV classes at SDN Watupecah and SDN Sumurpule. In this stage, students participated in learning activities using Torma Code media. The trial aimed to observe the practicality, attractiveness, and effectiveness of the media in enhancing students' critical thinking skills. Teachers and students assessed the media using practicality observation sheets, while effectiveness was measured using pretest and posttest critical thinking assessments. The final stage was Evaluation, which comprised both formative and summative evaluations. Formative evaluation was conducted at each development stage to refine the product before broader use, whereas summative evaluation was carried out after implementation to assess the overall effectiveness of the media. This evaluation ensured that Torma Code media could effectively improve students' critical thinking skills according to the established indicators.

The research subjects consisted of 15 students from SDN Watupecah, 15 students from SDN Sumurpule, two Grade IV teachers, and two expert validators. Subject selection was performed using purposive sampling to meet the needs of each development stage. The research stages involved analysis with SDN Watupecah students, development with expert validators, and implementation involving teachers and all Grade IV students from both schools. The instruments used in this study consisted of three main types. First, expert validation sheets, used to assess the feasibility of the media in terms of content, objectives, language, appearance, and technical quality (Harahap & Siregar, 2018). Second, practicality observation sheets, which included indicators of material suitability, relevance to the PBL model, stimulation of critical thinking, and language clarity. Third, critical thinking tests (pretest and posttest) in the form of essay questions, developed based on indicators of clarification, evaluation, inference, and problem-solving strategies (Ramadhani et al., 2022).

Data collection techniques included expert validation, practicality observation, and student critical thinking tests. Expert validation was conducted using assessment sheets, observation occurred during the learning process to monitor student interaction and media effectiveness, and critical thinking tests were administered before and after learning to measure improvements in students' abilities. Data analysis was conducted in three stages. First, expert validation analysis, where expert scores were calculated using the formula proposed by Akbar in Slamet (2022) and categorized as very valid, sufficiently valid, less valid, or invalid. Second, practicality analysis, based on teachers' and students' evaluations of the media's ease of use, categorized on a scale from very practical to impractical. Third, effectiveness analysis, conducted using paired sample t-tests to determine significant differences between pretest and posttest critical thinking scores (Ramadhani et al., 2022).

Additionally, N-Gain analysis was used to assess the level of improvement in critical thinking skills based on Hake's classification in Wahab et al. (2021), namely high ($g > 0.7$), medium ($0.3 \leq g \leq 0.7$), and low ($0 < g < 0.3$).

In conclusion, this research method was systematically designed through stages of needs analysis, media design, product development, implementation in elementary schools, and evaluation of effectiveness. Each stage was conducted based on measurable scientific principles and supported by expert validation, direct observation, and relevant statistical analysis to ensure that Torma Code interactive media based on Problem-Based Learning can genuinely enhance elementary students' critical thinking skills.

3. Results and Discussion

This study utilized the ADDIE development model (Analysis, Design, Development, Implementation, and Evaluation) to create the Torma Code interactive media, which serves as learning media for IPAS (Science and Social Studies Integration) in Grade IV elementary school. The product was designed to help students understand the concept of the Sense of Vision through an interactive and engaging learning experience based on Problem-Based Learning (PBL). The model aims not only to deliver content informatively but also to cultivate critical thinking and problem-solving skills from an early stage.

Analysis Stage

The analysis phase was conducted through classroom observations and interviews with IPAS teachers at SDN Watupecah and SDN Sumurpule. The results showed that students had difficulty understanding the concept of the sense of vision, particularly related to the impact of excessive gadget use on eye health. Learning activities were dominated by textbooks and lectures, causing limited student engagement, minimal inquiry-based activities, and insufficient opportunities for critical thinking. Teachers reported the need for interactive media that could support exploration, observation, and discussion. These findings align with Yuanta et al. (2024), stating that interactive learning media plays an important role in improving learning quality and fostering students' critical, collaborative, and creative thinking abilities. Therefore, it was concluded that learning media integrating observation tools and digital resources was required.

Design Stage

Based on the identified needs, the Torma Code interactive media was designed to align with the PBL model. The media is structured to guide students through problem identification, observation using concrete objects, digital exploration via QR/barcode scanning, group discussion, and reflective conclusion. The design process involved determining the physical structure of the media, content flow, learning activities, module layout, and assessment format. The media consists of a portable learning box, equipped with an eye torso model, a timeline board, and a mobile phone holder to simulate vision and light exposure from gadgets. Five barcode pockets located on the outer surface of the box direct students to educational videos, images, and problem scenarios related to eye health.

Worksheets and assessment rubrics were also created to support learning flow in accordance with PBL syntax.

Development Stage

During the development stage, the prototype of Torma Code was constructed by integrating the physical box, the torso eye model, timeline board, and barcode-linked digital contents. The final prototype presents visual and hands-on experiences, enabling students to investigate the effect of screen light on the human eye. The teaching module and student worksheets were finalized to align with PBL and critical thinking indicators (clarification, assessment, inference, and strategy). The completed prototype, along with its physical components, can be seen in Figure 1.

Figure 1. Final Prototype of Torma Code Interactive Media

Before testing the practicality and effectiveness of the product, the developed Torma Code interactive media was evaluated through expert validation. This process aims to ensure that the media meets quality standards in terms of content relevance, design feasibility, and technical accuracy before being implemented in the classroom. The validation involved two expert lecturers who assessed the media on alignment with learning objectives, content accuracy, practicality, clarity, user suitability, and technical quality. The results of the validation are presented in Table 1.

Table 1. Validation Results of Torma Code Interactive Media

Aspect	Average Score	Category
Alignment with objectives	3.5	Very Valid
Alignment with content	3.7	Very Valid
Practicality and flexibility	3.5	Very Valid
Ease of use	3.5	Very Valid
Suitability for target users	4.0	Very Valid
Technical quality	3.7	Very Valid
Overall Average	**3.7 (92.5%)**	**Very Valid**

Based on the results shown in Table 1, Torma Code achieved an overall score of 3.7 (92.5%), categorized as *Very Valid*. This indicates that the media is appropriate for use in learning without requiring major revisions. Validators noted that the media successfully integrates visual, physical, and digital elements to support student exploration and inquiry. The media was also found to be user-friendly, engaging, and aligned with curriculum objectives, making it suitable for PBL-based learning activities.

In addition to the media, a teaching module was developed as a guide for teachers in implementing the PBL learning stages using Torma Code. The module includes objectives, activity instructions, worksheets, and assessments aligned with critical thinking indicators. Before classroom use, the module underwent expert validation to ensure the clarity of content, alignment with PBL syntax, and appropriateness of language for fourth-grade students. Details of the module validation results are presented in Table 2.

Table 2. Validation Results of Teaching Module Using Torma Code Interactive Media

Aspect	Average Score	Category
Content feasibility	3.5	Very Valid
PBL model suitability	3.5	Very Valid
Assessment and evaluation	3.5	Very Valid
Language	4.0	Very Valid
Overall Average	**3.6 (90.27%)**	**Very Valid**

Table 2 shows that the teaching module achieved an overall score of 3.6 (90.27%) and was categorized as *Very Valid*. Validators confirmed that the module is well-structured, supports PBL implementation, and uses clear and communicative language suitable for students' cognitive development. Assessment components within the module were also deemed relevant for measuring critical thinking skills. Only minor revisions were recommended, mainly to further simplify instructions for student worksheets.

The critical thinking test instrument was developed to measure students' cognitive progress after using Torma Code. The instrument consists of items based on critical thinking indicators: clarification, assessment, inference, and strategy. To ensure the accuracy of the instrument, validation was conducted by experts focusing on content appropriateness, contribution of each item to the measured construct, and readability for students. The validation results are summarized in Table 3.

Table 3. Validation Results of Critical Thinking Test Instruments

Aspect	Average Score	Category
Content	3.5	Very Valid
Contribution	3.7	Very Valid
Language	3.8	Very Valid
Overall Average	**3.7 (92.5%)**	**Very Valid**

As shown in Table 3, the instrument obtained a total score of 3.7 (92.5%), falling into the *Very Valid* category. Experts considered the indicators accurate and representative of students' critical thinking skills. The language used in the test was also assessed as clear and understandable, allowing students to interpret questions independently. Minor adjustments were suggested for several items to simplify wording and ensure that questions are age-appropriate.

Implementation Stage

The implementation phase was carried out with two IPAS teachers and 30 fourth-grade students. The learning session followed the PBL sequence: presenting a real problem, observing the eye torso and screen light exposure, scanning barcodes to access digital content, discussing findings in groups, and making conclusions. Teachers acted as facilitators while students actively interacted with both physical and digital components of the media. To measure practicality, a questionnaire was distributed to both teachers and students. Results are shown in Table 4.

Table 4. Practicality Results Based on Teacher and Student Responses

Respondent	Score Obtained	Percentage (%)	Category
Teachers	37 of 40	92.5	Very Practical
Students	1,123 of 1,200	93.6	Very Practical

Table 4 demonstrates that both teachers (92.5%) and students (93.6%) rated Torma Code as *Very Practical*. Teachers stated that the media makes teaching easier by providing structured learning steps and clear visual references. Students reported that the media is enjoyable, interactive, and motivates them to participate actively during learning activities. These results confirm that Torma Code is feasible and efficient for classroom use.

Evaluation Stage

To evaluate the effectiveness of Torma Code in improving students' critical thinking skills, a pretest and posttest were administered. The data met the assumptions of normality and homogeneity, allowing the use of paired sample t-test analysis. This test aims to determine whether there is a significant difference in students' critical thinking scores after using the interactive media. The results are shown in Table 5.

Table 5. Paired Sample t-Test Results

Data Pair	Mean Difference	t	Sig. (2-tailed)
Pretest–Posttest	-24.5	-12.943	0.000

Table 5 shows a Sig. value of 0.000 ($p < 0.05$), indicating a significant difference between pretest and posttest scores. The negative t-value (-12.943) reflects a substantial improvement in students' results after the treatment. Thus, the use of Torma Code based on PBL is proven to significantly enhance students' critical

thinking skills. The findings confirm that interactive media combined with inquiry-based learning promotes deeper understanding.

To determine the level of improvement in critical thinking for each indicator, an N-Gain analysis was conducted. This analysis measures the increase in student scores based on four indicators: clarification, assessment, inference, and strategy. The improvement category is determined as low, medium, or high. The detailed improvement results for each indicator are shown in Table 6.

Table 6. N-Gain Results of Critical Thinking Ability

Indicator	Pretest Average	Posttest Average	N-Gain	Category
Clarification	65	78	0.37	Medium
Assessment	60	75	0.38	Medium
Inference	62	79	0.45	Medium
Strategy	58	76	0.43	Medium
Overall Average	**61.25**	**77**	**0.55**	**Medium**

Based on Table 6, the overall N-Gain score is 0.55 (Medium), which indicates a meaningful and consistent improvement in students' critical thinking skills. The highest improvement occurred in inference and strategy indicators, showing that students became more capable of concluding information logically and planning problem-solving strategies. These results reflect the success of Torma Code in stimulating students' analytical thinking through PBL activities.

Discussion

Validity of Torma Code Interactive Media

Based on validation by two experts in educational technology and 21st-century learning, the interactive media achieved a validity level of 92.50%, the teaching module 90.27%, and the test instruments 92.50%, all of which fall into the "very valid" category. These findings indicate that all development components met criteria for content feasibility, language, presentation, and the integration between media, teaching materials, and assessment tools. Theoretically, these results align with Yuanta et al. (2024), who demonstrated that the use of interactive digital media, such as Wordwall, can improve students' understanding of IPAS concepts by combining visualization, interactivity, and enjoyable learning experiences. Although the media characteristics differ Wordwall being digital and online, while Torma Code is a tangible product with a barcode system both share the same pedagogical principle: encouraging active student engagement through visualization and direct interaction with learning materials.

Handayani et al. (2022) further support this result, showing that STEM-based media development enhances elementary students' critical thinking and conceptual understanding. This suggests that integrating simple technology with real-world problem contexts, as applied in Torma Code, can strengthen content validity and functional effectiveness of learning media. Therefore, it can be concluded that Torma Code interactive media possesses high pedagogical, technical, and

contextual validity, making it suitable for IPAS learning to support the development of students' critical thinking skills.

Practicality of Torma Code Interactive Media

The practicality of Torma Code media was measured by its ease of use and usefulness for both teachers and students during the learning process. Questionnaire results indicated practicality scores of 92.5% from teachers and 93.6% from students, categorized as very practical. Teachers reported that the media was easy to operate, had clear usage instructions, and assisted in effectively delivering IPAS content. Meanwhile, students found the media engaging, easy to understand, and made learning more enjoyable and meaningful. These findings are consistent with Purnama et al. (2024), who found that applying PBL models with audiovisual media effectively improves students' critical thinking skills in science subjects. The common principle lies in PBL's orientation toward contextual problem-solving and active student engagement. Although the types of media differ audiovisual in Purnama et al., and tangible interactive barcode-based in this study both successfully create participatory and collaborative learning environments.

Lestari and Gunawan (2023) also confirmed that consistent PBL implementation enhances students' critical thinking, especially for practical science materials. Teachers act as facilitators, while students actively ask questions, engage in discussions, and draw conclusions based on empirical data. A similar pattern was observed in the use of Torma Code, where students not only received information but also explored learning by scanning codes, identifying problems, and finding solutions. This demonstrates that Torma Code is practical and supports higher-order thinking skills through collaborative and interactive learning experiences.

Effectiveness of Torma Code Interactive Media

Effectiveness was measured by comparing students' pretest and posttest critical thinking scores. Paired sample t-test results showed Sig. (2-tailed) = $0.000 < 0.05$, indicating a significant improvement in students' critical thinking after using Torma Code. The average N-Gain score of 0.55 falls into the medium category, demonstrating a considerable improvement in critical thinking skills. These results are consistent with Davidi et al. (2021), who found that STEM approaches enhance students' critical thinking through interdisciplinary problem-based analysis and reflection activities. Although the approaches differ, both studies emphasize the importance of learning experiences that stimulate students' analytical and problem-solving abilities. The findings are also supported by Amalia et al. (2021), who reported that Indonesian elementary students' critical thinking skills remain low, particularly in analysis and evaluation. By using Torma Code, students were given the opportunity to observe real phenomena and draw independent conclusions, thereby promoting significant improvement in critical thinking.

Additionally, Pratama and Hidayah (2024) support these findings, showing that Augmented Reality (AR) media significantly improves students' critical thinking and conceptual understanding. Although the media differ AR is digital, whereas

Torma Code is tangible with barcode integration both share the principle of providing exploratory and contextually problem-based learning experiences. Torma Code encourages students to interact directly with learning objects and construct knowledge through empirical observation, while AR provides immersive virtual experiences. Both approaches support student-centered learning, positioning students as active subjects in knowledge construction. This aligns with Sulthon et al. (2022), who emphasized that technology-based interactive media, both physical and digital, effectively create meaningful and contextual learning experiences. Thus, the findings indicate that Torma Code interactive media based on PBL is effective in enhancing elementary students' critical thinking skills. It creates contextual, collaborative, and enjoyable learning experiences while fostering higher-order thinking skills from an early stage.

Synthesis of Findings and Implications

Overall, this study reinforces findings from Yuanta et al. (2024); Handayani et al. (2022); Purnama et al. (2024); Lestari & Gunawan (2023); Pratama & Hidayah (2024), consistently confirming the effectiveness of integrating PBL models with interactive media to enhance elementary students' critical thinking. The three main components tested validity, practicality, and effectiveness yielded positive results and contributed collectively to creating relevant and meaningful 21st-century learning experiences.

Torma Code interactive media can be categorized as a learning product that is: (1) Valid, as it meets criteria for content feasibility, language, and alignment with learning objectives. (2) Practical, as it is easy to use, efficient, and receives positive responses from teachers and students. (3) Effective, as it demonstrably improves students' critical thinking through problem-based and exploratory learning activities. These results imply that PBL-based media not only enhance learning outcomes but also develop 21st-century skills such as critical thinking, collaboration, and problem-solving (Relitawati et al., 2024). Therefore, Torma Code media is suitable for widespread implementation in elementary schools as an innovative learning tool supporting Indonesia's educational transformation toward a student-centered "Merdeka Belajar" paradigm.

4. Conclusion

This study produced Torma Code interactive media based on Problem-Based Learning (PBL), which is valid, practical, and effective for teaching IPAS on the Sense of Vision in elementary schools. Expert validation results indicated that the media, teaching modules, and test instruments all received a "very valid" category, with an average feasibility above 90%, meaning that all development components met standards of content, language, and presentation. Practicality tests showed that both teachers and students responded positively, with scores above 92%, indicating that the media is easy to use, engaging, and supports meaningful learning processes. Furthermore, effectiveness tests revealed that the use of Torma Code interactive media significantly enhanced students' critical thinking skills. Paired-sample t-test

results showed a significant difference between pretest and posttest scores (Sig. < 0.05), and the average N-Gain score was 0.55, categorized as medium. The greatest improvements occurred in inference and thinking strategy aspects, indicating that the PBL model combined with interactive media encourages students to think analytically, reflectively, and problem-solvingly about real-world issues. Overall, the development of Torma Code interactive media has been shown to contribute to contextual, collaborative, and student-centered learning. This media not only helps teachers deliver content effectively but also fosters 21st-century skills, particularly critical thinking and problem-solving abilities. Therefore, Torma Code media is suitable for broader implementation in elementary schools as an innovative learning tool that supports the implementation of the Merdeka Curriculum and strengthens students' scientific literacy competencies.

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