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Articulate storyline-based multimedia development to improve the mathematical representation skills of grade V elementary school students

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Abstract

This research is motivated by the limited use of interactive multimedia, specifically designed to improve elementary school students' mathematical representation skills in integer operations materials. Previous studies have generally focused on improving learning outcomes without emphasizing mathematical representation as a key competency. Therefore, this study aims to develop and test the effectiveness of Articulate Storyline-based multimedia specifically designed to support students' mathematical representation abilities. This research uses the Research and Development (R&D) method with the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation. The study subjects were elementary school grade V students (n = 34) with an evaluation design using a one-group pretest–posttest. The primary instrument was a mathematical representation test, constructed based on NCTM indicators and operationalized as items assessing students' abilities to translate, interpret, and construct representations. The product's feasibility was validated by content experts (80%), subject matter experts (80%), media experts (97%), and field practitioners (96%), indicating that multimedia was in the very feasible category. The students' response to the product's practicality was also very good, with an average score of 96.42%. The results of the effectiveness test showed a significant improvement in students' mathematical representation abilities after using multimedia ($p < 0.001$), indicating that the product is not only feasible and practical but also pedagogically effective. The novelty of this research lies in the development of interactive multimedia in Articulate Storyline that explicitly integrates mathematical representation indicators into content design and learning activities. These findings make a practical contribution to the development of technology-based mathematics learning media aimed at strengthening the mathematical representation competence of elementary school students.

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1. Introduction

The development of the world in the 21st century is characterized by the use of information and communication technology in all aspects of life. However, *the World Economic Forum* in 2019 stated that Indonesia has low competitiveness and is only expected to be a "follower" in technology development (Schwab, 2019). There is an increase in the use of technology; all parties, especially in the education sector, need to be ready for the 21st century, given the technological advances that impact the quality of human resources (Bayley, 2022). One of the fields that plays a very important role and at the same time becomes a tool to improve the quality of human resources in the world of education is mathematics learning, because mathematics learning can be used as a forum for developing 21st-century skills that contain 4C skills, namely, *Critical thinking*, *Creativity*, *Communication*, *and Collaboration (Wulandari & Wulandari, 2016)*.

According to the *National Council of Teachers of Mathematics*, there are five competency standards that students must have in the mathematics learning process, namely problem solving, reasoning and proof, communication, connection, and representation (NCTM, 2009). Mathematics, as an abstract science filled with symbols, will be meaningless if interpreted inappropriately. This interpretation concerns the presentation of a concept in various ways to solve problems, namely by expressing mathematical ideas through pictures, graphs, tables, and verbal and symbolic representations. This is in line with Villegas' opinion in his research, mathematical representation can be said to be a practical tool that represents 3 elements, namely symbols, *pictorial*, and verbal (Villegas et al., 2009).

Ideally, when students encounter math problems during learning, they will try to understand and represent previously acquired information (Suryaningsih, 2019). Without good mathematical repetition skills, students will have difficulty understanding more complex mathematical concepts (Fuad Nasir et al., 2025). Conversely, when these skills are developed, students can more easily represent the relationships among mathematical ideas in various forms and develop a deeper understanding of problem-solving. This indicates how important mathematical representation skills are in mathematics learning activities.

Although mathematical representation skills are important in mathematics learning, students' skills remain low. Report results *from the Program for International Student Assessment (PISA) 2022 Vol. V shows that only 35.5% of Indonesian students can e*xpress mathematical information from diagrams, drawings, and graphs, while their ability to represent mathematical solutions in real-life contexts is only 30.9% (OECD, 2023). Research by Handayani and Yoga also showed that, among 45 students, only 24.9% had mathematical representation skills (Handayani & Yoga Juanda, 2018). This finding was strengthened by the researcher's interview with the mathematics teacher of class V MI Assa'adatuddarain I Pamulang, who stated that many students still have difficulty symbolizing and operating on simple numerical material. This is due to students' habit of imitating the teacher's method without developing their own mathematical representation skills. One cause of students' low representation skills is the habit of imitating the teacher's problem-solving approach without understanding concepts in depth (Johar et al., 2022). In addition, learning relies solely on printed books and whiteboards, which can be monotonous, so students are less enthusiastic about learning mathematics. The limited learning time at school is also an obstacle to the optimal development of this ability. Therefore, there is a need for facilities or tools in the form of learning media to improve mathematical representation skills.

Learning media is a means of bridging the gap between educators and students to enrich learning insights. Etymologically, the word media comes from the Latin medium, meaning

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intermediary or messenger. Mayer stated that the selection of learning media must be adjusted to the way the human mind works (Mayer & Fiorella, 2021). One of them is developing multimedia, namely, presentations that combine verbal and visual elements, as well as other interactive elements. One media format with potential is *Articulate Storyline*. By combining the presentation of audiovisual materials, *Articulate Storyline* will cover all the learning characteristics of students (Safira et al., 2021). Another advantage is that Articulate Storyline can be published on the web, making it easily accessible without the need for large storage space. This is also a solution to the limited learning time students have in class.

In contrast to previous research, this study focuses on multimedia-based development of *Articulate Storyline* to improve mathematical representation skills, especially in the material of operating numbers in grade V elementary school. This study uses the ADDIE development procedure, with the following stages: analysis, design, development, implementation, and evaluation (Reiser & Dempsey, 2018). Model. This development was chosen because it can guide the systematic, interactive design of learning media, ensuring high-quality products.

2. Method

This study uses the *Research and Development* (R&D), as Reiser and Dempsey suggested. *Research and development,* commonly referred to as development research, is a research method used to produce products with a structured instructional design process to test their effectiveness (Reiser & Dempsey, 2012). In this study, the Reiser and Dempsey development model is used, with the stages Analysis, Design, Development, Implementation, and *Evaluation* (ADDIE). The ADDIE model was chosen because it is often used to describe a systematic approach to instructional development. When used in development research, the stages are considered both sequential and interactive.

The research was conducted at MI Assa'adatuddarain I Pamulang in the even semester of the 2024/2025 school year. The subjects in the small-group trial were 10 students in class VB, while the large group consisted of 34 students in the same class. The research procedure carried out has several stages, namely: (1) *Analysis*, which consists of analyzing the needs, curriculum, and characteristics of students by conducting interviews with grade V teachers of Elementary and Pre-Research schools to obtain information about students' problems in learning, learning facilities, student learning styles, and student profiles. (2) *Design*, namely designing material manuscripts, *storyboards* and preparation of *research instruments* (3) *Development*, namely making multimedia using *Articulate Storyline*; after completing product development, then validating to experts consisting of question experts, material experts, media experts and field practitioners (4) *Implementation*, multimedia-based *The Articulate Storyline*, which has been categorized as feasible, was then tested on students through a small group trial consisting of 10 VB class students to find out its practicality and a large group trial on the total number of VB class students, namely, 34 students in calculating its effectiveness. (5) *Evaluation*, this stage consists of formative and summative evaluation. Formative evaluations are carried out at each stage of development and are based on comments from experts, practitioners, and learners on the assessment questionnaire, aiming to improve the developed product. Meanwhile, summative evaluation is conducted to assess the effectiveness of media in improving mathematical representation skills using *pretests* and *posttests*.

The instruments used in this study consisted of validation sheets, practicality sheets, and media effectiveness sheets. The validation sheet functioned as an expert and practitioner

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assessment tool containing various aspects and indicators without using tables, where expert validators assessed mathematical representation capabilities, language, questions, and implementation; material experts reviewed material quality, language, questions, and implementation; media experts examined visual components, navigation, and implementation; while field practitioners evaluated material relevance, language clarity, question quality, visual presentation, navigation, and implementation practicality. The media practicality sheet was administered to ten students to determine the practicality of the multimedia-based *Articulate Storyline* before wider implementation, covering five aspects: material, language, questions, visuals, and implementation. The media effectiveness sheet was used to measure learning effectiveness using pretest and posttest scores, which were analyzed with a paired-samples t-test in SPSS. Validation and practicality scores were calculated using the formula P(s) = S/N × 100%, where P(s) is the percentage of each sub-variable, S is the total score, and N is the maximum possible score; the results were then classified into five criteria, namely bad (≤ 35.9%), not good (36%–51.9%), enough (52%–67.9%), good (68%–83.9%), and excellent (84%–100%).

Data collection techniques in this research included interviews, questionnaires, and tests. Interviews served as a primary method to obtain initial information regarding the learning process, student difficulties, learning outcomes, efforts to improve learning, student characteristics, and available learning facilities (Fadhallah, 2021:41). The questionnaire used a Likert scale of 1–5 developed by Rensis Likert because it is widely applied to measure attitudes, opinions, and perceptions toward particular phenomena (Lasiyono & Sulistiyawan, 2024:159). Tests were also used to measure students' knowledge of the research variables, serving as a technique to assess respondents' cognitive mastery (Saat & Mania, 2020:97).

The study employed mixed methods combining qualitative and quantitative analysis to obtain stronger and more accurate results (Nadirah et al., 2022:67). Qualitative analysis involved processing verbal or non-numerical data (Jaya, 2020:07), taken from expert feedback, field trial responses, teacher interviews, and written suggestions on questionnaires, all of which guided improvements to the *Articulate Storyline* learning media. Quantitative analysis, defined as numerical data processing (Jaya, 2020:09), was used to evaluate media effectiveness by comparing pretest and posttest scores on mathematical representation abilities. Normality testing was conducted using the Shapiro–Wilk test because the sample size was below 50 (Ramadhani & Bina, 2021:196). If the p-value exceeded 0.05, the data were considered normally distributed and analyzed using a paired-samples t-test; if not, the Wilcoxon nonparametric test was applied. The paired-samples t-test used the total difference between groups (∑D) and the standard deviation (SD) to determine significant differences before and after using the multimedia-based *Articulate Storyline*.

3. Results

The learning media developed in this study use the ADDIE development model: Analysis, Design, and Development. This mathematics learning media produces multimedia on class V numeral material using the Articulate Storyline application. The results of the development of multimedia learning are aligned with the ADDIE model's stages.

3.1 Analysis

The initial stage in the ADDIE development model is the analysis stage, which aims to identify the reasons for developing multimedia-based Articulate Storyline and determine its intended

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users. At this stage, several analyses were conducted, beginning with a needs analysis through interviews with fifth-grade mathematics teachers at MI Assa'adatuddarain I Pamulang, which revealed obstacles such as low student interest, difficulties in understanding material, limited learning resources, restricted study time, and the monotonous use of media that quickly caused student boredom. Curriculum analysis further indicated that students had limited conceptual understanding, as they tended to rely heavily on memorized calculation procedures without comprehending the fundamental concepts of decimal numbers and their operations, and many struggled to represent or interpret the problem-solving steps involved in mathematical operations. Additionally, the analysis of student characteristics showed that learners were generally passive, classroom conditions were often less conducive, and students predominantly displayed visual and kinesthetic learning styles. Pre-research findings from a Google Form revealed that only 12 of 34 students met the minimum mastery criterion (KKM 70), and many experienced difficulties expressing mathematical symbols, reflecting cognitive representation constraints.

3.2 Design

The design stage in this study involved preparing material manuscripts and storyboards based on the results of the needs analysis, student characteristics, and curriculum review. The material script was developed in alignment with the learning objectives and expected outcomes for the topic of number operations. Storyboards were then created to outline the flow of the multimedia, including the main page, main menu, competency and learning objectives, materials, exercises, developer profiles, and user instructions. Additionally, assessment instruments were prepared for validation by material experts, media experts, question experts, field practitioners, and students, each tailored to the relevant assessment aspects required for evaluating the quality and feasibility of the developed media.

3.3 Development

At this stage, researchers began developing multimedia Articulate Storyline content based on what had been done during the analysis and planning stages. *The point* of this development is to create multi-learning in Articulate Storyline, with the aim of assisting students in understanding and improving their mathematical representation skills, especially in integer operations in class V MI/SD. Learning-based multimedia display *Articulate Storyline* can be seen in Figures 1 to 4.



Figure 1. ADDIE development model procedure



Figure 2. Menu utama media

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Figure 3. Learning Material Display



Figure 4. Drag and Drop *Question Form*

After the product is completed, a feasibility test is carried out by experts from the Lecturer of the Madrasah Ibtidaiyah Study Program, UIN Syarif Hidayatullah Jakarta, and a field practitioner, namely, a Mathematics teacher from class V at MI/SD. Problem experts are lecturers who have competence in compiling mathematics problems, material experts, namely lecturers who master the material of counting operations in accordance with the independent curriculum, and media experts, namely lecturers who are experienced in the field of digital learning media development, as presented in Table 1.

Table 1. Media validation results

Validator	Score	Eligibility Categories
Expert Questions	80%	Worthy/Good
Material Expert	80%	Worthy/Good
Media Member	97%	Very Well Deserved/ Very Good
Field Practitioner	96%	Very Well Deserved/ Very Good
Average Score	**88,25%**	**Very Well Deserved/ Very Good**

The validation results show that Articulate Storyline-based multimedia falls into a very decent category, as shown in Table 1, but several media experts provided input on *the layout* and *font* size to make it more user-friendly, as shown in Table 2. After the media has been revised based on input from media validators, the *Articulate Storyline-based* multimedia developed meets the criteria for being very valid or very feasible and is ready to be tested with students.

3.4 Implementation

In this stage, Articulate Storyline-based multimedia was tested with students in two stages: small-group and large-group trials. The small-group trial was conducted on Monday, February 10, 2025. Respondents in a small group trial of 10 students assessed the practicality of the media. The practicality of the media is shown in Table 3.

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Table 2. Results of the revision of the assessment by media validators

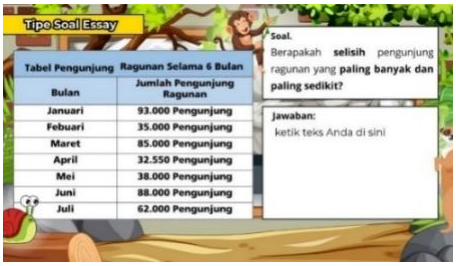
Before	After
	
Tip: Enlarge the money image, and turn *the layout* into *a landscape*	Revision: *The layout of* the money image has been redesigned into *a landscape*
	
Tip: Increase *the font* size of the table	Revision: Font size has been enlarged from 9 to 14.

Table 3. Results of media practicality assessment by students

Practicality Assessment Aspects	Result Score	Criterion Score	Average Score of Each Indicator	Criterion
Material	142	150	94.6%	Very Practical
Language	150	150	100%	Very Practical
Question	99	100	99%	Very Practical
Visual	178	200	89%	Very Practical
Practicality	199	200	95.5%	Very Practical
Overall Average	**153.6**	**160**	**96.42%**	**Very Practical**

The validation results showed that *Articulate Storyline-based* multimedia was found to be very practical, but one student provided input regarding the display, as shown in Table 4. As a result of students' practicality with media, the Articulate Storyline-based multimedia developed is ready to be tested in large groups to assess its effectiveness in improving mathematical representation skills, especially in the material for class V MI/SD integer operations. The effectiveness test was analyzed based on *the pretest and posttest results*. *The pretest* is conducted before the learning experience using Articulate Storyline-based multimedia, with 10 questions in *a Google Form*.

The average pretest score was 60.7, and the average posttest score was 71.9. The average increase in classical completeness of learning outcomes in mathematical representation skills was 32.35%. The percentage increase in mathematical representation ability in class V integer operation material is presented in Figure 5.

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Table 4. Results of the revision of the practicality assessment by students

Before	After
 Comment: Too much text in the explanation, sorting the number of counts	 Revision: Presentations are made into videos to attract students' attention to learning

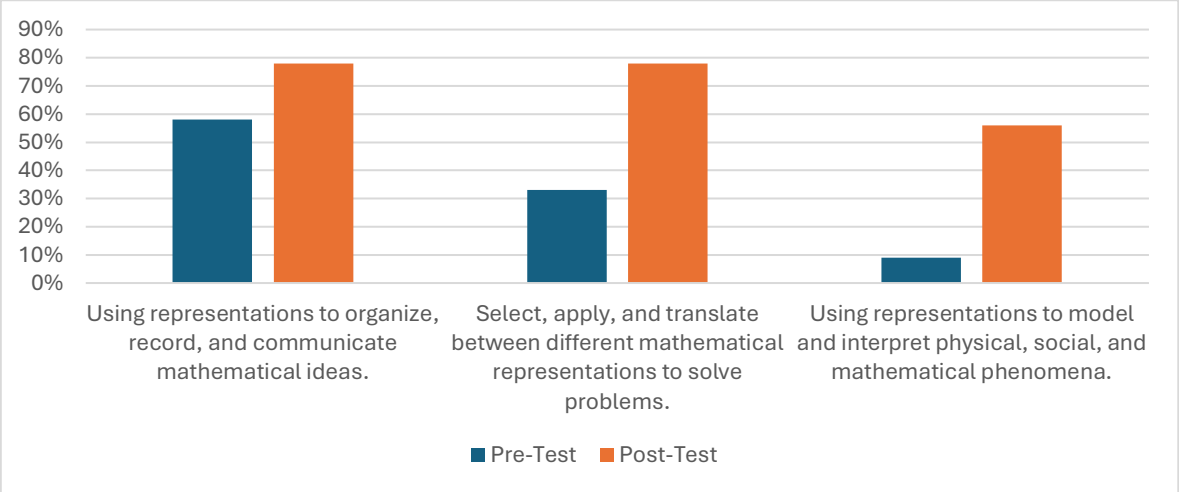


Figure 5. Percentage of improvement in mathematical representation ability in integer operation material for class V

Based on Figure 5, it can be seen that all indicators of mathematical representation ability, as defined by NCTM (2000), show a percentage increase in learning outcomes between before and after using multimedia-based *Articulate Storyline*. Next, conduct a paired-samples t-test; first, perform a normality test on the pretest and posttest data, as shown in Table 5.

Table 5. Shapiro-Wilk's normality test results

Shapiro Wilk			
Test Type	*Df*	*Sig (p-value)*	Information
Pretest	34	.351	Normally distributed data
Posttest	34	.159	Normally distributed data

Statistical results of the normality test, *Shapiro-Wilk*. It was found that the Pretest significance value (p-value) was 0,35. Meanwhile, in the *posttest, the* significance value (*p-value*) 0,159. The results of the normality test are good. *Pretest* or *posttest* obtains a *p-value* > 0.05. Therefore, the data are normally distributed. Furthermore, the data can be used to calculate a

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paired-samples t-test to determine whether there is a significant difference between the pretest and posttest results. The results of the t-test are presented in Table 6.

Table 6. Statistical test *results paired sample t-test*

T Test Statistics	Value
Mean	-11.176
Standard Deviation Difference	3.904
Standard Error Mean	0.670
t-value	-16.693
Df (Degree of Freedom)	33
p-value (Sig. 2-tailed)	**< 0.001**

Based on the results of the paired-samples t-test in Table 6, the value of t = -16.693 and p < 0.001 indicate a significant difference between *the pretest* and *posttest* results. Because the *Sig. (2-tailed)* at the level < 0.05, it can be concluded that the development of Articulate Storyline-based multimedia has a significant influence on improving mathematical representation skills, especially in the material for class V MI/SD numeral operations.

3.5 Evaluation

The evaluation stage in this study consists of both formative and summative evaluations, where formative evaluation is conducted throughout the media development process through expert validation and revisions based on feedback to improve the Articulate Storyline multimedia, while summative evaluation is carried out after media implementation through large group trials and analysis of pretest and posttest results to determine the media's effectiveness in enhancing students' mathematical representation skills; furthermore, examples of students' answers before and after using the media such as a question requiring students to sort numbers from smallest to largest and convert sentences into numerical symbols are presented in Tables 7 to 9 to illustrate the improvements observed.

Table 7. Analysis of question sorting numbers

Pretest Answers	Posttest Answers
Urutkanlah harga topi yang paling murah ke harga yang paling mahal ke dalam simbol angka! tujuh puluh delapan ribu lima ratus – enam puluh ribu lima ratus lima – tujuh puluh ribu – enam puluh lima ribu 78500-60555-70.000-65.000	Correct Answer: 60.505 - 65.000 - 70.000 - 78.500, Rp.60.505 - Rp.65.000 -Rp.70.000 - Rp.78.500, Rp60.505-Rp.65.000-Rp.70.000-Rp.78.500,60.505-65.000-70.000-78.500, 60.505 65.000 70.000 78.500, 60.505, 65.000,70.000, 78.500, 60.505,65.000,70.000,78.500 Student Answer: 60.505-65.000-70.000-78.500 Result: Correct

Based on Table 7, *the pretest answers,* there are still students who answered incorrectly to the sorting-numbers question. After being given learning using Articulate Storyline-based multimedia, only 4 students were wrong when presented with animated video material on Articulate Storyline. Interaction with multimedia helps students better understand the relationship between numbers in symbolic representation, so the indicator of representation ability that emerges is the ability to use representation to organize and communicate

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mathematical ideas. The question of calculating the nominal amount of money gives an order to calculate it from the banknotes, as shown in Table 8.

Table 8. Analysis of the counting numbers operation problem

Pretest Answers	Posttest Answers
Urutkanlah harga topi yang paling murah ke harga yang paling mahal ke dalam simbol angka! tujuh puluh delapan ribu lima ratus – enam puluh ribu lima ratus lima – tujuh puluh ribu – enam puluh lima ribu 78500-60555-70.000-65.000	Correct Answer: 60.505 - 65.000 - 70.000 - 78.500, Rp.60.505 - Rp.65.000 -Rp.70.000 - Rp.78.500, Rp60.505-Rp.65.000-Rp.70.000-Rp.78.500,60.505-65.000-70.000-78.500, 60.505 65.000 70.000 78.500, 60.505, 65.000,70.000, 78.500, 60.505,65.000,70.000,78.500 Student Answer: 60.505-65.000-70.000-78.500 Result: Correct

Based on Table 8, the *students' pretest* answers show a clear calculation flow. After being given a learning experience using Articulate Storyline, students better understand the concept of calculation through the visualization of animated images and animated videos of counting operations. In the *posttest,* students can translate or translate visual representations into symbolism by correctly arranging mathematical equations. Thus, the indicator that appears in the ability to mathematical representation is the ability to translate mathematical representations. This question gives an order to calculate the unit price for 4 snacks purchased, as shown in Table 9.

Table 9. Analysis of the counting numbers operation problem

Pretest Answers	Posttest Answers
Urutkanlah harga topi yang paling murah ke harga yang paling mahal ke dalam simbol angka! tujuh puluh delapan ribu lima ratus – enam puluh ribu lima ratus lima – tujuh puluh ribu – enam puluh lima ribu 78500-60555-70.000-65.000	Correct Answer: 60.505 - 65.000 - 70.000 - 78.500, Rp.60.505 - Rp.65.000 -Rp.70.000 - Rp.78.500, Rp60.505-Rp.65.000-Rp.70.000-Rp.78.500,60.505-65.000-70.000-78.500, 60.505 65.000 70.000 78.500, 60.505, 65.000,70.000, 78.500, 60.505,65.000,70.000,78.500 Student Answer: 60.505-65.000-70.000-78.500 Result: Correct

Based on Table 9, the *students' pretest* answers are dominated by a lack of clear calculation flow. After being given a learning stimulus in Articulate Storyline, students better understand the concept of calculation through visualizations and animated videos of counting operations. In the *posttest,* students can answer questions by modeling mathematical equations well to calculate correctly based on the visualized real situation. This indicates that students are more helpful in relating mathematical concepts to visualizing real situations in *Articulate Storyline-based* multimedia. Thus, the indicator that appears in the ability to mathematical representation is the ability to use representation to model and interpret physical, social, and mathematical phenomena.

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4. Discussion

The findings of this study indicate that the Articulate Storyline-based multimedia was not only technically feasible and practically acceptable, but also instructionally effective in strengthening elementary students' mathematical representation skills in whole-number operations. The significant improvement observed after the intervention suggests that the multimedia did more than increase students' engagement; it appears to have supported students in organizing mathematical ideas, translating contextual information into symbolic form, and interpreting visual representations more accurately. In other words, the instructional value of the developed product lies in its capacity to structure learning experiences in ways that make abstract mathematical content more cognitively accessible to Grade V learners. This interpretation is consistent with evidence that digital technology tends to yield stronger effects in mathematics when it serves as a support for problem-solving, communication, and conceptual processing rather than as a mere delivery tool (Ran et al., 2022). It also aligns with evidence that visualization-based interventions have a meaningful positive effect on mathematics learning across topics and learner groups (Schoenherr et al., 2024).

From a theoretical perspective, these findings can be understood through the lens of representation theory and multimedia learning. Duval (2006) argues that mathematical comprehension depends fundamentally on students' ability to coordinate and convert between different semiotic registers, such as verbal, visual, and symbolic forms. In the present study, the improvement in students' post-intervention performance may therefore be interpreted as evidence that the multimedia helped learners perform these representational conversions more successfully. This is especially important in elementary mathematics, where students often execute procedures without fully grasping the conceptual meaning embedded in mathematical notation. The findings can also be interpreted in light of multimedia learning principles. By combining animation, written explanations, audiovisual support, and interactive exercises in a sequenced format, the developed media likely reduced representational ambiguity and enabled learners to focus on relevant mathematical relationships. In this sense, the multimedia did not simply present content attractively; it functioned as a scaffold that supported the transition from concrete or contextual meaning toward formal mathematical representation.

The present findings are also in line with prior empirical studies, both international and author-related, although this study offers a more specific focus on mathematical representation. Hoogland et al. (2018) found that students performed significantly better when contextual mathematical problems were presented in depictive rather than purely descriptive form, suggesting that visually supported representations can preserve meaning and facilitate mathematical interpretation. Likewise, Abraham & Prediger (2025) show that digital multi-representation environments become more powerful when learners are supported through well-sequenced tasks and targeted scaffolds that help them connect graphical and symbolic forms. These two studies help explain why the current multimedia may have been effective: its design appears to have supported not only exposure to multiple representations, but also movement between them. This interpretation is further reinforced by Suryaningsih et al. (2025), who demonstrated that the Concrete Pictorial Abstract approach significantly improved elementary students' numeracy skills by guiding learners progressively from concrete experiences to pictorial support and then to abstract symbolism. Similarly, Suryaningsih et al. (2024) reported that problem-solving-based interactive video worksheets improved numerical literacy, indicating that digital mathematics materials are most effective when they are designed around structured cognitive processes. In addition, Suryaningsih & Zulfatunnisa (2025) found that the Creative

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Problem-Solving mod, supported by fraction puzzle media, significantly improved students' mathematical problem-solving ability, suggesting that visual and concrete supports can strengthen the organization of mathematical ideas during learning. Compared with those studies, the present research extends the discussion by showing that Articulate Storyline-based multimedia can be specifically oriented toward strengthening mathematical representation as a core competence, rather than merely improving numeracy, problem-solving, or general achievement.

Accordingly, the main contribution of this study lies in demonstrating that interactive multimedia can be designed not merely to attract learners' attention, but also to support representational competence in elementary mathematics explicitly. This contribution is important because many studies on digital mathematics learning still emphasize broad outcomes such as motivation, achievement, or general engagement, while fewer studies focus directly on representation as a central mathematical process. The present study contributes to that gap by showing that multimedia design, content structure, and student interaction can be deliberately aligned with representation indicators. In this respect, the study also contributes to current discussions on the use of high-quality representations in mathematics classrooms, which emphasize that the educational value of multiple representations depends on how explicitly their relationships are made available to learners (Dreher et al., 2024). Therefore, the novelty of this study lies not simply in the use of Articulate Storyline as a digital platform, but in the integration of mathematical representation into the logic of instructional design itself.

Despite these contributions, several limitations should be acknowledged. First, the study employed a one-group pretest-posttest design, which limits the strength of causal inference because the observed gains cannot be compared directly with those of a control group. Second, the study was conducted in a single school context with a relatively limited sample, so the generalizability of the findings remains constrained. Third, the effectiveness evidence was derived from short-term post-intervention outcomes, meaning that the durability of students' representational gains over time has not yet been established. These limitations suggest that future studies should employ more rigorous experimental or quasi-experimental designs, involve broader and more diverse samples, and examine whether representation-oriented multimedia continues to produce stable effects across mathematical topics and over longer instructional periods. Such follow-up research would be valuable for confirming the robustness of the present findings and for extending the evidence base on digitally supported representational learning in elementary mathematics.

5. Conclusion and Implications

The development of multimedia based on *Articulate Storyline* has succeeded in addressing the needs of mathematics learning by making it more interesting, meaningful, and in line with the characteristics of elementary school students, in accordance with the ADDIE development model procedures. The results of validation by material experts, media experts, question experts, and field practitioners indicate a high level of feasibility, with an average of 88.25% in the very feasible category.

Implementation tests in small and large groups showed increased student engagement, especially after the material presentation was changed from text to an interactive video format. *The students' positive response was in line with high assessments in the* technical, visual, language, and material substance aspects, with an average percentage of 96.42%. Formative

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and summative evaluations were conducted to assess the overall effectiveness of the media. Based on the results of the statistical analysis, a t-count of -16.693 with a significance of < 0.001 was obtained in the paired-samples t-test, indicating a significant difference in students' mathematical representation abilities before and after using multimedia.

It can be concluded that the multimedia developed has a positive and significant influence on improving students' mathematical representation skills. Thus, *Articulate Storyline-based multimedia is* feasible and practical to use as an innovative learning medium that effectively supports the mathematics learning process, especially in the operation of counting numbers.

Declaration of Statements

The authors did not provide information or include statements concerning the CRediT Authorship Contribution Statement, Declaration of Competing Interest, Data Availability Statement, Ethical Declaration, and Declaration of AI Statement in the submitted manuscript.

References

Abraham, M., & Prediger, S. (2025). Scaffolding fifth graders' learning with a digital multi-representation applet: Design research on focusing multiplicative structures with dynamic dot arrays. Digital Experiences in Mathematics Education, 11(2), 219-246. https://doi.org/10.1007/s40751-024-00156-7

Bayley, S. H. (2022). Learning for adaptation and 21st-century skills: Evidence of pupils' flexibility in Rwandan primary schools. International Journal of Educational Development, 93, 102642. https://doi.org/10.1016/j.ijedudev.2022.102642

Dreher, A., Wang, T.-Y., Feltes, P., Hsieh, F.-J., & Lindmeier, A. (2024). High-quality use of representations in the mathematics classroom: A matter of the cultural perspective? ZDM - Mathematics Education, 56(5), 965-980. https://doi.org/10.1007/s11858-024-01597-5

Duval, R. (2006). A cognitive analysis of problems of comprehension in learning mathematics. Educational Studies in Mathematics, 61(1), 103-131. https://doi.org/10.1007/s10649-006-0400-z

Fadhallah, R. A. (2021). Wawancara. UNJ Press.

Fuad Nasir, Gunawan, Nurhidayah, S., Anindiyah, S., Elwanda, Y. I. P. P., Setiyani, Khodari, R., Sundawan, M. D., & Laelasari. (2025). Students' mathematical representation ability in learning fractions through a concrete-representational-abstract approach with joyful learning. Primary: Jurnal Pendidikan Guru Sekolah Dasar, 14(5), 643-658. https://doi.org/10.33578/jpfkip.v14i5.p643-658

Handayani, H., & Juanda, R. Y. (2018). Profil kemampuan representasi matematis siswa sekolah dasar di Kecamatan Sumedang Utara. Primary: Jurnal Pendidikan Guru Sekolah Dasar, 7(2), 211-217. https://primary.ejournal.unri.ac.id/index.php/JPFKIP/article/view/1011

Hoogland, K., de Koning, J., Bakker, A., Pepin, B. E. U., & Gravemeijer, K. (2018). Changing representation in contextual mathematical problems from descriptive to depictive: The effect on students' performance. Studies in Educational Evaluation, 58, 122-131. https://doi.org/10.1016/j.stueduc.2018.06.004

Jaya, I. M. L. M. (2020). Metode penelitian kuantitatif dan kualitatif: Teori, penerapan, dan riset nyata. Anak Hebat Indonesia.

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Johar, R., Khairunnisak, C., & Rohaizati, U. (2022). Students' mathematical representation ability in learning algebraic expressions using realistic mathematics education. Jurnal Didaktik Matematika, 9(1), 151-169. https://doi.org/10.24815/jdm.v9i1.25434

Lasiyono, U., & Sulistiyawan, E. (2024). Metode penelitian kuantitatif. Mega Press Nusantara.

Mayer, R. E., & Fiorella, L. (2021). Principles for managing essential processing in multimedia learning: Segmenting, pre-training, and modality principles. In R. E. Mayer & L. Fiorella (Eds.), The Cambridge handbook of multimedia learning (3rd ed., pp. 243-260). Cambridge University Press. https://doi.org/10.1017/9781108894333.025

Nadirah, Pramana, A. D. R., & Zari, N. (2022). Metodologi penelitian kualitatif, kuantitatif, mix method: Mengelola penelitian dengan Mendeley dan NVivo. CV Azka Pustaka.

National Council of Teachers of Mathematics. (2000). Principles and standards for school mathematics. National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (2009). Focus in high school mathematics: Reasoning and sense making. National Council of Teachers of Mathematics.

OECD. (2023). PISA 2022 results: Factsheets Indonesia. https://oecdch.art/a40de1dbaf/C108

Ramadhani, R., & Bina, N. S. (2021). Statistika penelitian pendidikan: Analisis perhitungan matematis dan aplikasi SPSS. Kencana.

Ran, H., Kim, N. J., & Secada, W. G. (2022). A meta-analysis on the effects of technology's functions and roles on students' mathematics achievement in K-12 classrooms. Journal of Computer Assisted Learning, 38(1), 258-284. https://doi.org/10.1111/jcal.12611

Reiser, R. A., & Dempsey, J. V. (2012). Trends and issues in instructional design and technology (3rd ed.). Pearson.

Reiser, R. A., & Dempsey, J. V. (2018). Trends and issues in instructional design and technology (4th ed.). Pearson.

Safira, A. D., Sarifah, I., & Sekaringtyas, T. (2021). Pengembangan media pembelajaran interaktif berbasis web Articulate Storyline pada pembelajaran IPA di kelas V sekolah dasar. Prima Magistra: Jurnal Ilmiah Kependidikan, 2(2), 237-253. https://doi.org/10.37478/jpm.v2i2.1109

Saat, S., & Mania, S. (2020). Pengantar metodologi penelitian: Panduan bagi peneliti pemula. Pusaka Almaida.

Schoenherr, J., Strohmaier, A. R., & Schukajlow, S. (2024). Learning with visualizations helps: A meta-analysis of visualization interventions in mathematics education. Educational Research Review, 45, 100639. https://doi.org/10.1016/j.edurev.2024.100639

Schwab, K. (2019). The global competitiveness report. World Economic Forum.

Suryaningsih, T. (2019). Hard work and problem-solving based on Krulik-Rudnick's heuristic theory on project-based learning with the OQALE approach of 5th-grade elementary school students. JMIE: Journal of Madrasah Ibtidaiyah Education, 3(1), 91-99. https://doi.org/10.32934/jmie.v3i1.101

Suryaningsih, T., Ratnaningsih, S., & Ramadhan, F. (2024). The development of a math student worksheet through interactive videos focused on problem-solving to improve numerical literacy. AIP Conference Proceedings, 3058(1), 060028. https://doi.org/10.1063/5.0201290

Suryaningsih, T., Nisa, K., Widiyanto, R., Latip, A. E., & Siron, Y. (2025). Enhancing elementary students' numeracy skills through the Concrete-Pictorial-Abstract (CPA) approach.

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Journal of Integrated Elementary Education, 5(1), 224-236. https://doi.org/10.21580/jieed.v5i1.25383

Suryaningsih, T., & Zulfatunnisa, S. (2025). The influence of the Creative Problem-Solving model assisted by fraction puzzle media on problem-solving ability in mathematics learning. JENIUS (Journal of Education Policy and Elementary Education Issues), 6(1), 101-118. https://doi.org/10.22515/jenius.v6i1.10306

Villegas, J. L., Castro, E., & Gutiérrez, J. (2009). Representations in problem solving: A case study with optimization problems. Electronic Journal of Research in Educational Psychology, 7(17), 279-308.

Wulandari, N., & Wulandari, N. (2016). Analisis kemampuan literasi sains pada aspek pengetahuan dan kompetensi sains siswa SMP pada materi kalor. EDUSAINS, 8(1), 66-73. https://doi.org/10.15408/es.v8i1.1762.

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