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Development of math journey game media based on triple code model for dyscalculia students

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ABSTRACT

In mathematics learning, students often require concrete, interactive, and engaging learning media to help them understand basic arithmetic more easily. Students with dyscalculia required special attention because they experienced difficulties in understanding numbers and basic arithmetic operations. This study aimed to develop an educational game called *Math Journey* based on the Triple Code Model as an alternative learning medium that supported students with dyscalculia in learning basic arithmetic. This study employed a Research and Development method using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. The development process involved material experts, learning media experts, and teachers as practitioners to evaluate the feasibility and practicality of the product. The subjects of this study were four elementary school students with dyscalculia. Data were collected through material validation sheets, media validation sheets, teacher practicality assessment sheets, and learning outcome tests. The results showed that the game achieved a material feasibility score of 90.91% and a media feasibility score of 95.68%, both categorized as very feasible. The practicality assessment by teachers reached 100%, indicating a very feasible category. Furthermore, the effectiveness test using the N-gain score yielded a value of 0.78, which indicated that the game media was effective for students with dyscalculia. Overall, the *Math Journey* game based on the Triple Code Model was proven to be feasible, practical, and effective in supporting basic arithmetic learning and provided an enjoyable learning experience for students with dyscalculia.

Keywords: Mathematics, Game, Triple Code Model, Dyscalculia, Basic Arithmetic.

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INTRODUCTION

Mathematics plays an important role in education as it helps develop logical, systematic, and critical thinking skills. Beyond being a school subject, mathematics also contributes to assisting individuals in solving various problems in daily life (Nikolić & Hilčenko, 2024). Therefore, understanding basic mathematical concepts needs to be established from an early age to prevent learning difficulties in subsequent educational levels (Popescu, 2021).

However, in the practice of teaching mathematics in elementary schools, not all students are able to understand the concepts taught well. Various studies show that there are still students who experience difficulties in learning mathematics, even classified as having specific learning disorders. One form of such disorder is dyscalculia, a condition characterized by difficulties in understanding numbers, mathematical symbols, and performing basic

arithmetic operations (Sinaga & Simarmata, 2020). Dyscalculia can be experienced by children with normal intelligence levels and is often characterized by a gap between intellectual potential and academic ability in mathematics (Fakhriya, 2022).

Research conducted by Azhari (2024) identified the existence of elementary school students in Indonesia who experience dyscalculia, thus demonstrating that difficulty in arithmetic is a real problem in mathematics learning. This condition needs serious attention because if not handled properly, difficulty in learning mathematics can have an impact on low learning achievement and decreased student motivation in the long term. In line with this, Raharjo (2024) reported that of the 209 elementary school students studied, there were 13 children with difficulties in arithmetic or dyscalculia.

One effort that can be made to help students with dyscalculia is through the use of learning media that suit their characteristics and needs. Concrete media are considered capable of bridging abstract mathematical concepts to make them easier to understand through real and manipulative experiences (Annisah, 2017). In addition, learning media packaged in the form of educational games also have the potential to increase student motivation and engagement in the mathematics learning process (Cahyati & Rhosalia, 2020).

The development of learning media for students with dyscalculia needs to be based on a theoretical foundation regarding how children process mathematical information. One relevant theory is the Triple Code Model, which explains that understanding numbers and mathematical operations is processed through three cognitive codes, namely verbal code, visual code, and magnitude code (Bender & Beller, 2011). Obstacles in one or more of these codes are often the cause of the main difficulties in calculating experienced by dyscalculic students, especially in basic arithmetic operations such as addition and subtraction. According to Rockhill et al. (2024), different neural substrates encode the processing of visual, auditory, and non-symbolic numerical representations, supporting and extending the Three-Code Model framework for numerical cognition in the brain, which aligns with how gaming activities involve verbal, visual, and numerical representations during learning. Obstacles in one or more of these codes are often the cause of the main difficulties in calculating experienced by dyscalculic students, especially in basic arithmetic operations such as addition and subtraction.

Although several studies have developed learning media for students with dyscalculia, most of them focus on digital applications or general classroom instruction and do not explicitly integrate the Triple Code Model into concrete game-based learning. Therefore, there is still limited research on board game media grounded in the Triple Code Model specifically designed for students with dyscalculia in special schools.

This study introduces a concrete educational game that systematically integrates all three cognitive codes of the Triple Code Model into play-based learning activities specifically designed for students with dyscalculia. Based on this research gap, this study aimed to develop the *Math Journey* educational board game based on the Triple Code Model to support basic arithmetic learning for students with dyscalculia.

METHOD

The type of research used is R&D (Research and Development). Darmawan (2019) stated that research and development is a series of systematic activities in designing and producing new products, as well as improving existing products, so that the results can be empirically validated. According to Okpatrioka (2023), Research and Development (R&D) is the process or steps involved in developing a new product or improving an existing product. Development research is used to identify needs, develop products, and validate those products as new products that meet those needs. This research procedure uses the ADDIE model as a reference for development. According to Zamsiswaya (2024), the ADDIE model consists of the stages of analysis, design, development, implementation, and evaluation. In this study, the

ADDIE stages were carried out up to the development stage, which included product design and expert validation, followed by limited field testing to evaluate the initial feasibility, practicality, and effectiveness of the developed product.

This study involved subject matter experts and game media experts as evaluators of the suitability of the developed product, as well as teachers as partitioners who assessed the practicality of using the game in learning activities. The effectiveness of the product was examined through a comparison of pre-intervention and post-intervention results. The educational game was implemented in a limited trial involving four students ($n = 4$) with specific learning difficulties in dyscalculia, who acted as users in the field testing stage. This limited number of subjects was intentional, as the study focused on initial product testing rather than large-scale implementation.

The data collected in this study were qualitative and quantitative. Qualitative data were obtained in the form of written feedback and revision notes provided by validators and teachers during the game development process based on the ADDIE model stages. Quantitative data were obtained from the results of validation scores, practicality assessment, and pre-intervention and post-intervention tests used to measure the effectiveness of the game.

The research instruments consisted of a game material validation assessment sheet, a game media validation assessment sheet, and a game practicality assessment sheet completed by teachers. In addition, pre-intervention and post-intervention test sheets were used to assess students' learning outcomes before and after using the educational game.

Before implementing the educational game, a pre-intervention test was administered as a screening stage to identify students who experienced difficulties in basic arithmetic. The test was developed based on indicators of dyscalculia in addition and subtraction operations. Students who scored below 60 were categorized as having specific learning difficulties in arithmetic and were selected as research subjects, while students who scored 60 or above were not categorized as students with dyscalculia and were not included in the implementation stage.

Data collection was conducted by distributing validation and assessment sheets during the evaluation stage. The validation sheets were submitted to subject matter experts and game media experts. The practicality of the game was assessed by teachers after the game was implemented. Pre-intervention tests were administered before the limited field testing, and post-intervention tests were administered after students used the educational game. To assess the effectiveness of the Triple Code Model-based educational game, dyscalculic students completed two sets of tests during the pre-intervention and post-intervention stages.

The collected data were analyzed by examining the results of material validation, media validation, and practicality assessments conducted by teachers. The results of these analyses were used as a basis for determining the feasibility and practicality of the developed educational game. The effectiveness of the product was analyzed by comparing students' pre-intervention and post-intervention scores. The following formula was used to analyze the results of the validation and practicality questionnaires.

$$P = \frac{f}{N} \times 100\%$$

Explanation:

f = total data collection results

N = maximum score

P = percentage

Thus, the validity of the game materials and media can be determined from the following percentages:

Table 1. Percentage of Material and Media Validity Criteria

Percentage	Criteria
0% - 49%	Not suitable
50% - 59%	Sufficiently suitable
60% - 79%	Suitable
80% - 100%	Very suitable

Practicality can be calculated using the percentage formula below:

$$P = \frac{f}{N} \times 100\%$$

Explanation:

f = total data collection results

N = maximum score

P = percentage

So that practicality can be determined by the following percentages

Table 2. Percentage of Media Practicality Criteria

Percentage	Criteria
0% - 49%	Not practical
50% - 59%	Sufficiently practical
60% - 79%	practical
80% - 100%	Very practical

The N-gain score was used to measure learning improvement because it is appropriate for pre-test and post-test designs with a small sample size. Therefore, the following formula presents the N-gain calculation used to measure the effectiveness of learning improvement in students with dyscalculia.

$$g = \frac{S_{\text{post-intervention}} - S_{\text{Pre-intervention}}}{S_{\text{max}} - S_{\text{pre-intervention}}}$$

The N-gain assessment category for measuring learning outcomes are as follows:

Table 3. Effectiveness categories

Score	Category
$g \geq 0,3$	Low Efevective
$0,3 \leq g < 0,7$	Medium Efevective
$g \geq 0,7$	High Efevective

RESULT

This study produced a learning game media developed based on the Triple Code Model approach for students with dyscalculia in basic arithmetic learning, particularly addition and subtraction. The study was conducted at a special school with students who had specific learning difficulties, namely dyscalculia. The media was developed by following the ADDIE model stages, which include analysis, design, development, implementation, and evaluation.

The initial stage carried out was the analysis stage. At this stage, researchers analyzed the curriculum used in schools and assessed the learning needs of students with dyscalculia.

The results of the analysis showed that schools had implemented the Merdeka Curriculum with adjustments to learning outcomes in accordance with the conditions and abilities of students in Special Schools. In addition, from the results of observations and interviews, it was found that the use of concrete learning media in basic arithmetic learning was still limited. As a result, students often have difficulty understanding numbers and arithmetic operations. Therefore, learning media that is concrete, easy to use, and can make students more interested in the learning process is needed.

The second stage is the design stage. At this stage, researchers begin to design learning games by considering the learning characteristics of students with dyscalculia. The games are designed based on the Triple Code Model approach, so that play activities do not only focus on calculation results, but also on the process of understanding numbers and quantities. Game activities are organized based on three forms of representation, namely verbal, visual, and magnitude. Verbal representation occurs when students mention numbers and calculation results verbally, visual representation is seen from the use and movement of game tools, while magnitude representation is demonstrated through an understanding of the sum and difference of numbers with the help of concrete objects.

The next step is development, where the game design is then realized into a game medium that is ready for use. The game medium is made using a game board, pawns, dice, number cards, question cards, and fruit cards as concrete aids. Each square on the game board contains different instructions, such as recognizing numbers, addition, and subtraction. In this way, students can learn to count through guided and fun play activities.

After the game media has been developed and printed, the first stage of validation is carried out, namely material validation. Material validation is carried out by two experts who assess the suitability of the material content with the learning objectives, the clarity of the concepts of addition and subtraction, and the suitability of the material with the characteristics of dyscalculic students, language use and presentation. Input from material experts is used as a basis for improving and refining the game media before it is used in the next stage.

The following are the results of material validation from both validators

Table 4. Material Validation Results

Aspects Assessed	Validator	f	N	Percentage (%)	Average (%)
Material	V1	15	16	93,75%	96,88%
Suitability	V2	16	16	100%	
Concept	V1	9	12	75%	79,17%
Clarity	V2	10	12	83,33%	
Use of	V1	8	8	100%	100%
Language	V2	8	8	100%	
Presentation	V1	7	8	87,50%	87,50%
	V2	7	8	87,50%	
Total					90,91%

The table above shows that the material suitability aspect of both validators obtained an average percentage of 96.88%, the concept clarity aspect of both validators obtained an average percentage of 79.17%, then the language usage aspect obtained an average of 100% from the assessment of both validators. The presentation aspect obtained an average score of 87.50%. The overall average score is 90.91%, which falls into the “highly acceptable” category.

The results of the material validation showed positive responses from experts, with input in the form of adjustments to learning outcomes to suit the characteristics of dyscalculic students in special schools. In general, the material has met the objectives, accuracy of content, clarity of presentation, and relevance to student learning needs.

Next, media validation was carried out by media experts through a validation questionnaire. The following are the results of the media validation.

Table 5. Media Validation Results

Aspects Assessed	Validator	f	N	Percentage (%)	Average (%)
Display	V1	21	24	87,50%	93,75%
	V2	24	24	100%	
Interactivity	V1	15	16	93,75%	96,87%
	V2	16	16	100%	
Consistency	V1	28	28	100%	96,42%
	V2	26	28	92,85%	
Total					95,68%

Table 5 shows that media validation in terms of appearance by both validators obtained an average percentage of 93.75%, interactivity by both validators obtained an average percentage of 96.87%, and consistency obtained an average score of 96.42%. The overall average score was 95.68%, which falls into the “highly acceptable” category. This media validation was conducted once, with the media criteria being “highly acceptable.”

Next, validation by practitioners was carried out by fifth-grade teachers, with the validation results presented as follows:

Table 6. Practitioner Validation Results

Aspects Assessed	f	N	Percentage (%)
Clarity of Learning	8	8	100%
Wearability	12	12	100%
Feasibility	12	12	100%
Total			100%

Table 7 shows that practitioner validation in terms of learning clarity obtained 100%, then usability 100% and feasibility 100%. With an average score of 100% in media validation, the practitioner validation results fall into the “highly feasible” category.

The learning game media developed in this study was in the form of a board game equipped with cards and concrete aids. The game was then used in learning activities as part of a trial of the application of media in basic arithmetic material. The trial was conducted on fifth-grade students at SLBN Prof. Dr. Sri Soedewi Masjchun Sofwan, S.H., Jambi. Before implementing the game media, students were given preliminary questions (pre-intervention) aimed at determining their initial abilities in basic arithmetic, particularly in addition and subtraction. Six students participated in the pre-intervention activity. The following are the pre-intervention results for 6 students.

Table 7. Pre-intervention Results

Subject	Skor
S-1	30
S-2	50
S-3	40
S-4	50
S-5	70
S-6	90

The test results showed that two students scored above the specified criteria, while the other four students scored below the criteria. Thus, the four students who showed difficulties in basic arithmetic were selected as subjects for the application of learning game media.

After the test subjects were determined, the Triple Code Model-based game media was applied through structured play activities. In this activity, students were actively involved in addition and subtraction using game boards, cards, and concrete aids. During the learning process, students were not only guided to perform calculations, but also to understand number concepts through verbal number naming, the use of visual representations, and the concrete meaning of quantities and differences.

At the end of the learning activity, students were given a final test with a level of difficulty equivalent to the initial test. The final test results showed a change in students' basic arithmetic skills after participating in learning using game media. These changes were then analyzed by comparing the initial and final test results. To determine the level of improvement in student abilities, an N-Gain calculation was performed, with the analysis results presented in the following table.

Table 8. Pre-intervention and post-intervention results

Subject	Pre-intervention	Post-intervention	N-Gain
S-1	40	90	0,83
S-2	50	80	0,6
S-3	30	80	0,57
S-4	50	100	1
Total	170	350	

$$g = \frac{S_{\text{post-intervention}} - S_{\text{Pre-intervention}}}{S_{\text{max}} - S_{\text{Pre-intervention}}} = \frac{350 - 170}{400 - 170} = \frac{180}{230} = 0,78$$

Based on Table 8, it can be seen that of the four students tested, the pre-intervention average score was 42.5 and the post-test average score was 87.5. From these average scores, it can be seen that there was a significant improvement. From the scores obtained, two students experienced a medium improvement and two students experienced a high improvement. The overall N gain score is 0.78, so the use of game media is categorized as effective.

The fifth stage in the media development process is evaluation. At this stage, researchers review the game media that has been developed to assess its feasibility, ease of use, and impact on student learning. The evaluation involves subject matter experts, media experts, teachers, and students as users of the media in learning activities.

The assessment by subject matter experts focused on the suitability of the learning content, clarity of concepts, use of language, and presentation of material in the game. The assessment results showed an average score of 90.91%, indicating that the material in the game media was in line with the learning objectives and characteristics of students with dyscalculia. Furthermore, the media expert's assessment reviewed the appearance, interactivity, and consistency of the use of rules and symbols in the game. The evaluation results showed an

average score of 95.68%, indicating that the media was considered interesting, easy to understand, and supported active student engagement during learning.

Teachers as learning practitioners assessed the clarity of learning objectives, ease of use of the media, and its suitability for use in the classroom. The assessment results showed a score of 100%, indicating that the game media was very easy to use and suitable for learning conditions at the Special School.

In addition, evaluation was conducted through media use trials with students. The comparison between pre-intervention and post-intervention scores showed a significant improvement in students' basic arithmetic skills. The average student score increased from 42.5 to 87.5, with an N-gain value of 0.78, which is classified as high and indicates effective learning improvement. This improvement occurred because students were directly involved in play activities that combined reading and reciting questions, observing the movement of pawns and the results of dice rolls, and understanding numbers through the use of concrete aids.

Based on the evaluation results, it can be concluded that the developed game media has met the criteria of feasibility, ease of use, and effectiveness in helping students with dyscalculia understand the concepts of addition and subtraction. This evaluation stage also serves as the basis for refining the media so that it can be used more optimally in future learning.

DISCUSSION

The results of material validation by experts indicated that the addition and subtraction content presented was relevant to the learning objectives and appropriate for students with dyscalculia. The material was organized in a gradual manner and integrated with concrete activities, thereby supporting more meaningful and less abstract understanding of basic arithmetic. These findings are consistent with the study by Stasolla et al. (2025), which demonstrated that gradually structured educational game-based media can improve numerical understanding in students with mathematical learning difficulties. In addition, Polydoros (2025) emphasized that the delivery of mathematical concepts through concrete media facilitates student sensory and cognitive engagement, thereby supporting a more comprehensive conceptual understanding.

In terms of conceptual clarity, the percentage score obtained was lower than other aspects but still within an acceptable range. This finding indicates that the mathematical concepts were conveyed adequately, although certain parts still require strengthening. This result is in line with the findings of Hornos-Arias et al. (2025), who reported that an educational game based on cognitive codes supports students in gradually developing numerical understanding. Furthermore, the high and clear use of language aligns with the result of Mawaddah and Wijastuti (2023), which showed that clear instructions facilitate students' ability to follow learning activities effectively.

The media validation results indicated that the visual design of the game was attractive, interactive, and consistent, thereby facilitating students' attention and engagement during learning activities. These findings are consistent with the studies by Prisilia et al. (2025) and Rhera and Hendriani (2025), which reported that visually appealing and interactive educational media can enhance focus and learning motivation among students with dyscalculia. Furthermore, the consistency of rules, symbols, and gam flow helped students understand how to play the game more easily, supporting the findings of Syafiyah et al. (2024), who stated that consistency in game design improves the effectiveness of game-based learning.

Practitioners' assessments further indicated that the game media was easy to use, had clear learning objectives, and could be implemented without increasing teachers' workload. This finding is in line with the study by Rahayu et al. (2021), educational media can be integrated into classroom learning without adding to teachers' instructional burden and is suitable for students with special learning difficulties.

The effectiveness of the developed media was evident from the significant increase in students' average scores after the intervention, with an N-Gain value of 0,78, which falls into the high category. This result is consistent with the findings of Stasolla et al. (2025) and Hornos-Ariaset et al. (2025), who reported that game-based learning can improve students' understanding of basic mathematical operations, particularly among learners with dyscalculia. The play activities, which involved reading problem cards, observing pawn movements, rolling dice, and using concrete aids, enabled students not only to perform calculations mechanically but also to understand the concepts of more and less and changes in numerical values. These processes support the principles of the triple code model, which emphasizes the integration of verbal, visual, and magnitude representations in numerical learning, (Bender & Beller, 2011)

The integration of verbal, visual, and magnitude representations in the math journey game helped students connect numerical symbols with words, visual cues, and real-life experiences, which is consistent with the findings of Polydoros, (2025) and Prisiliaet et al. (2025) This combination of representations made the learning process more meaningful and supported the improvement of students' arithmetic skills. In addition, the physical and visual interactions involved in the gameplay strengthened multisensory engagement, as highlighted by Hornos-Ariaset et al. (2025), resulting in better post-intervention learning outcomes compared to those observed before the use of the game-based media.

The combination of these three forms of representation makes the learning process more meaningful for students with dyscalculia. Activities such as reading questions, observing the movement of pawns and dice, and interpreting numbers through concrete objects help students gradually build a basic understanding of arithmetic. This is one of the factors that supports the improvement of students' abilities after using the Triple Code Model-based game media.

The results obtained in this study indicate that the game media developed is capable of providing meaningful learning support for students with dyscalculia. The high feasibility scores from the material, media, and practitioner validators indicate that the game has been designed in accordance with the learning needs of students, both in terms of content and application. The systematically structured flow of activities, accompanied by clear and consistent game rules, helps students follow the learning process in a more focused manner. This condition allows students to focus more on understanding basic arithmetic concepts without experiencing difficulties during the learning activities.

In addition, the improvement in student abilities seen in the post-intervention results shows that learning using game media has a positive impact on basic arithmetic comprehension. During the activity, students were actively involved in the counting process through the use of game boards, cards, and concrete aids. This activity encouraged students to understand the concepts of addition and subtraction through direct experience, rather than simply memorizing procedures. Physical and visual involvement in the game helped students build an understanding of changes in numerical values, so that the learning outcomes obtained after the intervention showed better progress than before the use of game media.

CONCLUSION AND SUGGESTIONS

This study developed a Triple Code Model-based learning game media to support students with dyscalculia in understanding basic arithmetic, particularly addition and subtraction. The media was developed using the ADDIE model to align the learning activities with the characteristics and learning needs of students with special needs, particularly through concrete, visual, verbal, and numerical learning experiences. The findings indicate that the developed media is highly feasible and practical for learning basic arithmetic. The validation and implementation results demonstrate that the content, visual design, interactivity, and usability of the media meet the expected criteria. The implementation of the media also showed

improvement in students' basic arithmetic abilities, suggesting that the integration of verbal, visual, and numerical representations through the Triple Code Model can support students with dyscalculia in developing their understanding of basic arithmetic concepts through engaging learning activities.

For further development, future research could explore variations in game activities and develop other forms of games based on the Triple Code Model to provide more diverse and engaging learning experiences. The media could also be implemented over a longer period and with a broader range of participants to examine the consistency and sustainability of students' understanding of basic arithmetic concepts. Further research may also investigate how different forms of representation within the Triple Code Model contribute to the learning processes and mathematical development of students with dyscalculia.

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