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Designing a Game-Based PMRI Learning Trajectory on Money Value Equivalence for Autistic Students

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Abstrak

Penelitian ini bertujuan mengembangkan lintasan belajar bagi siswa autistik untuk memahami konsep kesetaraan uang melalui permainan Monopoli yang dimodifikasi, di mana konteks berenang di Opi Waterfun ditempatkan sebagai salah satu petak dalam papan permainan. Menggunakan penelitian desain yang mencakup tiga tahap, desain awal, eksperimen pembelajaran, dan analisis retrospektif. Penelitian ini melibatkan delapan siswa autistik kelas VIII dengan level kemampuan berada pada kategori menengah (moderate), ditandai dengan keterbatasan komunikasi sosial dan kesulitan berpikir abstrak. Data dikumpulkan melalui observasi, rekaman video, dan hasil kerja siswa untuk mengidentifikasi lintasan belajar aktual yang muncul selama kegiatan bermain. Hasil penelitian menunjukkan bahwa penggunaan rupiah dalam konteks berhenti pada petak aktivitas berenang, seperti membeli tiket masuk dan menyewa pelampung, membantu siswa mengenali, membandingkan, dan mengombinasikan nilai uang secara bermakna. Lintasan belajar berkembang dari mengenali pecahan uang, menghitung total biaya, hingga melakukan pembayaran kontekstual secara tepat. Berdasarkan prinsip PMRI, permainan Monopoli yang dimodifikasi secara kontekstual dapat membuat pembelajaran matematika lebih adaptif, menyenangkan, dan inklusif bagi siswa autistik.

***Kata Kunci**: Penelitian Desain; Pendidikan Inklusif; Lintasan Belajar; Kesetaraan Nilai Uang; PMRI.*

Abstract

This study aims to develop a learning trajectory for autistic students to understand the concept of money value equivalence through a modified Monopoly game, in which a swimming context at Opi Waterfun is embedded as one of the board spaces. The study employed a design research methodology consisting of three phases, preliminary design, teaching experiment, and retrospective analysis. It involved eight eighth-grade autistic students with moderate-level abilities, characterized by limitations in social communication and difficulties in abstract thinking. Data were collected through observations, video recordings, and student work to identify the actual learning trajectory that emerged during the game-based activities. The findings show that the use of Indonesian rupiah within the swimming activity space, such as purchasing entry tickets and renting float rings, helped students recognize, compare, and combine money values meaningfully. Their learning trajectory progressed from identifying denominations and calculating total costs to making accurate contextual payments. Guided by PMRI principles, the contextually modified Monopoly game supports mathematics learning that is more adaptive, engaging, and inclusive for autistic students.

Keywords: design research; inclusive education; learning trajectory; money value equivalence; PMRI.

I. INTRODUCTION

Meaningful and contextual mathematics learning is a crucial need in inclusive education, particularly for students with autism spectrum disorder (Iovannone et al., 2003; Zhang et al., 2022). Autistic children have unique characteristics that affect their learning process, such as difficulties in verbal communication, abstract thinking, and limitations in understanding symbols and numbers in conventional ways (Desiningrum, 2016; Magyar, 2010; Sabaruddin et al., 2020). Therefore, mathematics instruction for autistic students must be designed using concrete and visual approaches, tailored to their everyday experiences. One relevant and essential topic in real life is understanding the concept of money equivalence.

However, money-related tasks present unique challenges for autistic students. Many autistic learners struggle with understanding symbolic representations, and currency values require interpreting numbers that are not visually proportional to their worth such as recognizing that a Rp. 10,000 bill is worth more than a larger Rp. 2,000 bill. In addition, autistic students often experience difficulty generalizing concepts across contexts, making it challenging to transfer newly learned money skills outside the classroom. Sequential calculations such as combining bills, calculating totals, and determining change require working memory and flexible thinking, which are areas commonly impacted in autism. These challenges reinforce the need for concrete, visual, and highly contextualized learning media, such as PMRI-based activities, to support meaningful understanding of money equivalence.

Understanding the value of money is vital for autistic children as it supports their independence and life skills. However, difficulties in recognizing currency denominations, calculating total costs, and adjusting payment amounts to match the price of goods or services often become significant challenges. These limitations can be addressed through engaging and easy-to-understand approaches. In this context, using real-life experiences such as swimming, an activity familiar to children, becomes an effective alternative to introduce basic concepts of money.

The “Let’s Go Swimming” activity in this student book is designed to help students understand money value and equivalence through the context of swimming at Opi Waterfun. Through this activity, students observe ticket and rental prices, recognize currency denominations, and compose combinations of money to make payments. This instructional strategy incorporates simple storytelling, visual aids, and step-by-step instructions to support the mathematical understanding of autistic students in a gradual and structured way. This aligns with previous findings which emphasize that digital or contextualized instructional designs can enhance mathematical problem-solving skills for students with autism (Blanco et al., 2024), while gamified and augmented learning environments have also been shown to improve socio-emotional skills in autistic students (López Bouzas & Moral Pérez, 2023). Furthermore, (Marhamah et al., 2025) highlights through a systematic literature review that mathematics learning

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for children with special needs requires contextual approaches and adaptive strategies, making activities like "Let's Go Swimming" highly relevant.

The learning design in this activity adopts the Indonesian Realistic Mathematics Education (PMRI) approach, which emphasizes real-life contexts, concrete models, and active student participation. PMRI has been proven effective in facilitating students' mathematical understanding through direct experience and interaction within a meaningful learning environment (Zulkardi, 2002). Furthermore, (Putri, 2023) emphasizes that the PMRI approach can help teachers develop meaningful mathematics learning. This shows that PMRI is not only relevant in general education but can also be adapted to meet the special needs of autistic students. In line with this, (Honorato et al., 2024) highlights that game-based learning provides effective support for students with autism spectrum disorder by enhancing engagement and fostering adaptive learning strategies. Moreover, (Talantseva et al., 2023) notes that the global prevalence of autism spectrum disorder among children underscores the importance of implementing diverse and inclusive instructional approaches such as PMRI.

II. METHOD

This study utilizes the Design Research technique, which strives to improve the quality of classroom teaching practices through an interactive analytical process of learning hypotheses that integrate students' thinking processes and classroom dynamics (Gravemeijer & Cobb, 2006a) According to (Baumgartner et al., 2002), design research is a systematic and adaptable strategy for improving educational quality while simultaneously establishing or confirming a theory of learning processes known as the Local Instruction Theory. LIT is a hypothesis on how students learn specific mathematical topics, and how instructional tools or media might support that process (Gravemeijer & van Eerde, 2009).

This study adopts the Indonesian Realistic Mathematics Education (PMRI) approach, which connects real-life contexts from students' everyday experiences as the starting point for learning. Previous research has also shown that PMRI-based teaching materials can effectively improve students' mathematical problem-solving abilities and provide meaningful learning experiences (Bellinda et al., 2023). Design research consists of three main phases: (1) Preliminary Design, (2) Teaching Experiment, and (3) Retrospective Analysis (Bakker, 2004; Gravemeijer & Cobb, 2006b).

1) Preliminary Design

This phase aims to construct a Hypothetical Learning Trajectory (HLT), which includes learning goals, learning activities, and hypotheses about students' thinking processes (Van den Akker et al., 2006). The designer first examines the middle school mathematics curriculum—specifically the topic of currency value—and the learning characteristics of eighth-grade autistic students. Initial observations are conducted to identify student

conditions, prior experiences, and potential local contexts, particularly swimming activities at Opi Waterfun. In addition, (Kurniawan et al., 2018) highlights that educational games can be effectively used in mathematics learning for autistic students, while (Yuliana & Rizqia, 2022) emphasizes that game-based strategies support autistic students' engagement in learning mathematics.

The learning activity designed at this stage focuses on understanding currency values and calculating money in the context of purchasing entrance tickets and renting swim rings. This context is chosen because it is familiar to the students and can support mathematics learning in a concrete, visual, and enjoyable manner

In this phase, the Hypothetical Learning Trajectory (HLT) was formed based on the assumption that students would initially recognize currency denominations through visual prompts, subsequently develop the ability to combine bills to match given values, and ultimately make accurate payments in contextual problem situations. It was also hypothesized that embedding the learning activity in a familiar real-world context would reduce cognitive demand associated with abstract thinking and enable gradual conceptual development.

2) Teaching Experiment

In this step, the learning trajectory created in the preliminary stage is executed in classroom instruction. The aim is to identify and understand students' thinking strategies and how they construct mathematical concepts, particularly the concept of money value. This process involves two cycles. The first cycle, or pilot experiment, serves as an initial evaluation of the learning trajectory, including activities such as identifying ticket prices and rental fees in the swimming context at OPI Waterfun. Findings from this cycle are used to refine the instructional design. The second cycle is the main teaching experiment, which applies the revised learning trajectory to ensure alignment with the characteristics of autistic students.

Given the communication characteristics of autistic students, data were collected not only through verbal responses but also through non-verbal indicators, including gestures, pointing, nodding, and task engagement. Short, structured verbal prompts were used during instructional questioning, while students' understandings were triangulated through worksheet completion, recorded classroom interactions, and behavioral observations captured in video recordings.

3) Retrospective Analysis

In this final phase, all data from the teaching experiments are thoroughly analyzed to evaluate the alignment between the initial hypotheses stated in the HLT and the actual classroom implementation, particularly in Activity 2 involving swimming and calculating ticket and rental costs. The analysis is conducted collaboratively by the researcher and supervising lecturer to ensure the validity of findings. This process aims to deepen the understanding of how students construct social arithmetic concepts, such as adding money and comparing prices. In the design research approach, success is not only measured by the achievement of final learning objectives, but also by the discovery of effective instructional

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principles that are relevant to the needs of autistic students.

III. Result and Discussion

The implementation of the learning trajectory in the "Let's Go Swimming" activity shows that a contextual approach using visualization and concrete activities can effectively support autistic students in understanding the concept of money value in everyday life. This activity features a swimming theme at Opi Waterfun, a setting familiar to students, and is integrated with the calculation of ticket and swim ring rental prices as the learning context. Based on the results of the needs analysis through interviews, pretests, and curriculum review, a Hypothetical Learning Trajectory (HLT) was developed, as shown in Figure 1, using the swimming context featured on one of the spaces of the modified Monopoly board.

The Monopoly game used in this study was modified to make it more accessible for autistic students. The modifications included simplifying the number of spaces, replacing abstract illustrations with concrete images, and enlarging the font and play money to make them easier for students to recognize. An example of the modified game board is shown in Figure 2.

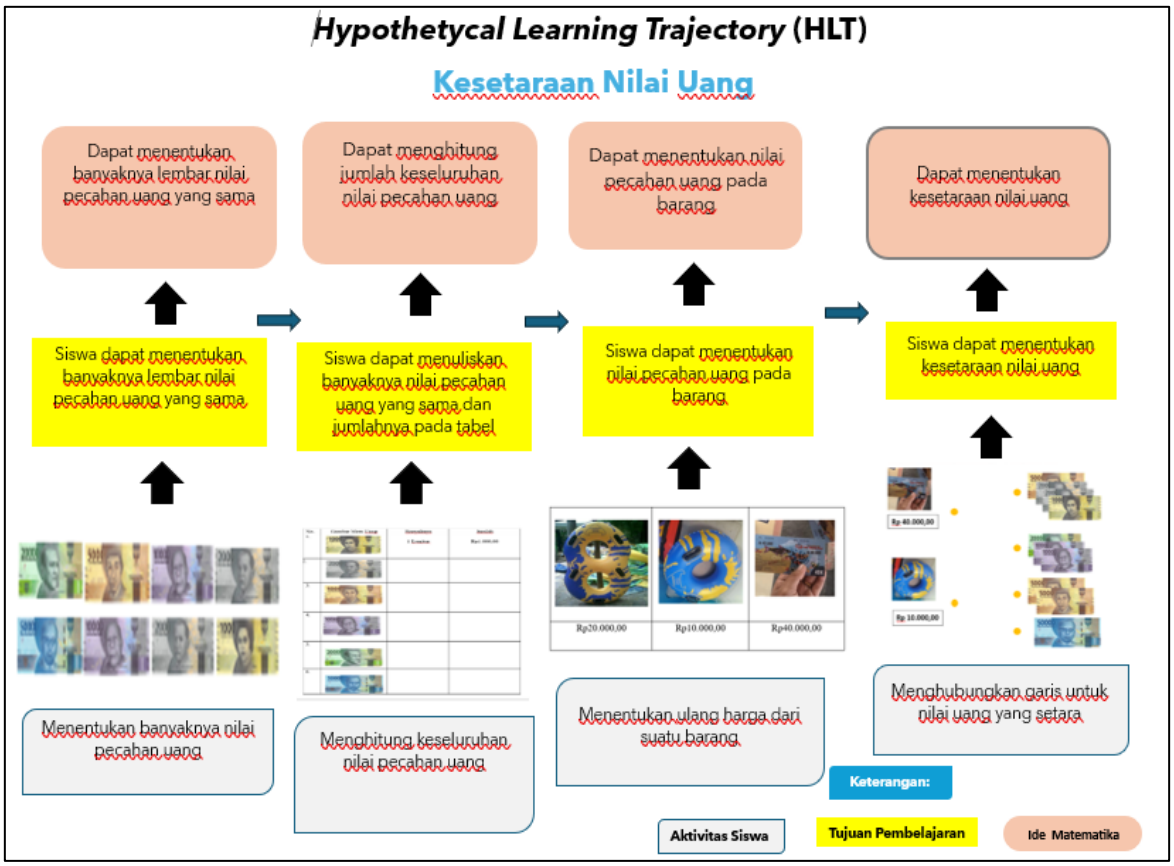

Figure 1. HLT of Money Equivalence.

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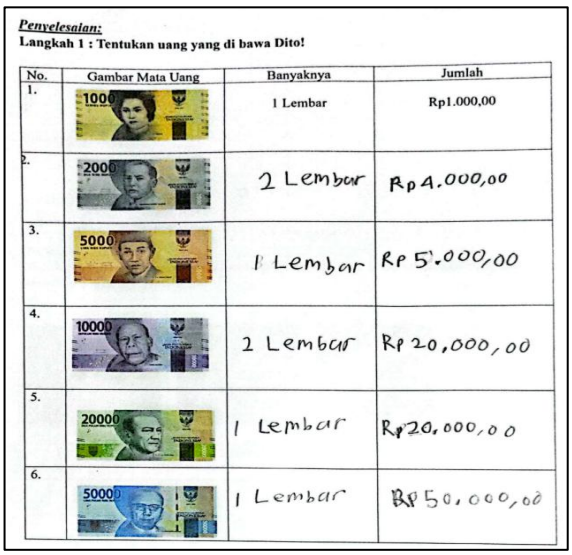
Figure 2. Modified Monopoly Board.

Activity 1: Identifying the Number of Currency Denominations

The teacher introduces information about entrance ticket prices for Opi Waterfun, which vary between weekdays and weekends, along with the rental fees for single and double swim rings. Students are shown a simple brochure displaying these prices in both visual (images) and text formats. At the beginning of the activity, the teacher introduces a picture of the swimming pool and explains the activities of swimming and renting swim rings. The teacher then guides students in reading the ticket prices (Rp40,000 on weekdays and Rp60,000 on weekends) as well as the rental fees (Rp10,000 for a single ring and Rp20,000 for a double ring). This activity is carried out by showing images of money and the price brochure to make it easier for students to understand. This indicates that students begin to recognize currency denominations and can state the total amount based on the visual representations. This supports Desiningrums' (2016) view that children with autism tend to respond better to visual stimuli and concrete activities that are adapted to their personal experiences.

Activity 2: Calculating the Total Value of Currency Denominations

In this activity, the teacher engages students in calculating the total amount of money Dito brings and comparing it to the ticket and swim ring rental prices. During this session, the teacher instructs students to write down the ticket and rental prices, determine the number of bills and the total amount of money, and calculate the overall total.



Penyelesaian:
Langkah 1 : Tentukan uang yang di bawa Dito!

No.	Gambar Mata Uang	Banyaknya	Jumlah
1.	100	1 Lembar	Rp1.000,00
2.	2000	2 Lembar	Rp 4.000,00
3.	5000	1 Lembar	Rp 5.000,00
4.	10000	2 Lembar	Rp 20,000,00
5.	20000	1 Lembar	Rp 20.000,00
6.	50000	1 Lembar	Rp 50,000,00

Figure 3. Student Answer on Activity 2.

The teacher additionally interviewed one of the students to strengthen the findings derived from the student's activity sheet. A summary of the interview results is presented below.

Teacher: "Dear, try to count how many bills does Dito have?".
Student: "(While counting) There are eight".
Teacher: "Good! Now, count how many bills have the same picture."
Student: "(Student nods)".
Teacher: "What denomination is this bill?".
Student: "Two thousand".
Teacher: "How many two-thousand bills are there?".
Student: "There are two".

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Teacher: "Yes, that's right. How much is the total if there are two two-thousand bills?".
Student: "Four thousand".
Teacher: "Now add up the total amount of money Dito has".
Student: "(Student nods)".

The interview between the teacher and the student above shows that the student was able to count the number of bills Dito had (8 bills), group the bills based on the same denomination (Rp2,000), and determine the total value of two Rp2,000 bills as Rp4,000. The student's active responses—such as counting, nodding, and correctly stating the denomination—indicate that the PMRI approach, through concrete learning using worksheets, helped the student better understand the concept of money value and the process of addition. PMRI emphasizes that relevant contexts and real-life experiences are essential in building a bridge between students' everyday lives and mathematical concepts.

Activity 3: Recalculating the Price of an Item

Activity 3 aims to develop autistic students' understanding of recalculating the price of an item based on real-life contexts, in this case, swimming at Opi Waterfun. In this activity, students were given the ticket and rental prices and asked to recalculate the total cost and strategize how to use their available money accordingly. Observation results show that most students were able to identify and name currency denominations and correctly add up the cost of tickets and swim ring rentals. In addition, students were able to subtract the total cost from their available money to determine the remaining amount. The learning process progressed gradually, starting from visual observation, manipulation of money images, to simple calculations. The use of familiar contexts and concrete media proved effective in helping students understand the concept of money value and its application. This activity also encouraged active student participation in discussions and trained their ability to make decisions based on available information. These findings reinforce that the PMRI approach, when supported with relevant contexts, is effective in helping autistic students meaningfully understand social arithmetic concepts.

Figure 4. Student Answer on Activity 3.

Activity 4: Matching Lines for Equivalent Money Values

The activity of drawing lines between pictures of money and their equivalent values is designed to help autistic students practice recognizing currency denominations and understanding the equivalence between different denominations. In this activity, students are shown images of various currency bills (such as Rp2,000, Rp5,000, Rp10,000, and so on) on one side, and their equivalent values in the form of numbers or money combinations on the other side. The students' task is to draw matching lines between the corresponding pairs.

Observation results show that most students were able to identify the relationship between the money images and their numerical values with a fairly high level of accuracy. Some students were also able to verbally state the value of the money while visually matching the correct pairs, such as connecting two Rp1,000 bills with the number Rp2,000. This activity not only supports students in understanding nominal values but also reinforces the concept that the same amount of money can be represented in different denominations.

The use of a simple and structured visual format proved effective for students with cognitive and communication challenges, as it supports associative thinking and sustained attention. Therefore, this activity plays an important role in building a concrete and enjoyable foundation for understanding the concept of money equivalence.

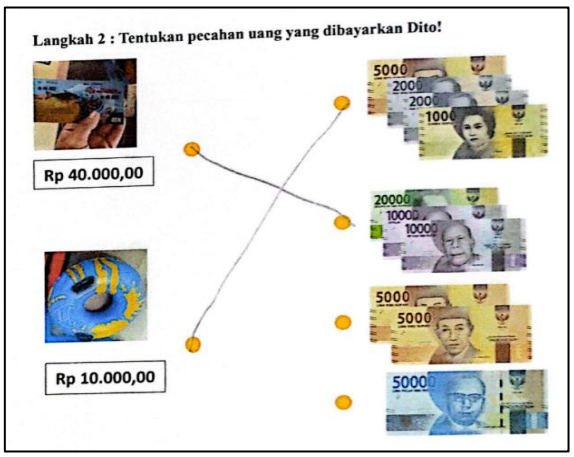

Figure 5. Student Answer on Activity 4.

The development of students' understanding throughout the activities can be mapped using the iceberg model (Figure 6). At the Real Situation level, students directly engaged with the Monopoly game context featuring Opi Waterfun and were required to interpret authentic scenarios, such as purchasing entrance tickets on Monday and renting a swim ring, as well as determining the total payment needed. At the Model Of level, students began identifying price information by recording ticket and rental fees in a simple table and determining the amount that had to be paid. Their thinking progressed to the Model For level when they grouped play-money denominations, selected the appropriate currency notes, and matched combinations of bills to obtain the correct total. Finally, at the Formal Mathematics level, several students were able to write the addition operation numerically and calculate the total payment independently without visual support or contextual prompts. This progression illustrates how autistic students gradually transition from concrete experiences to formal mathematical representation through PMRI-supported contextual learning and the use of modified Monopoly media.

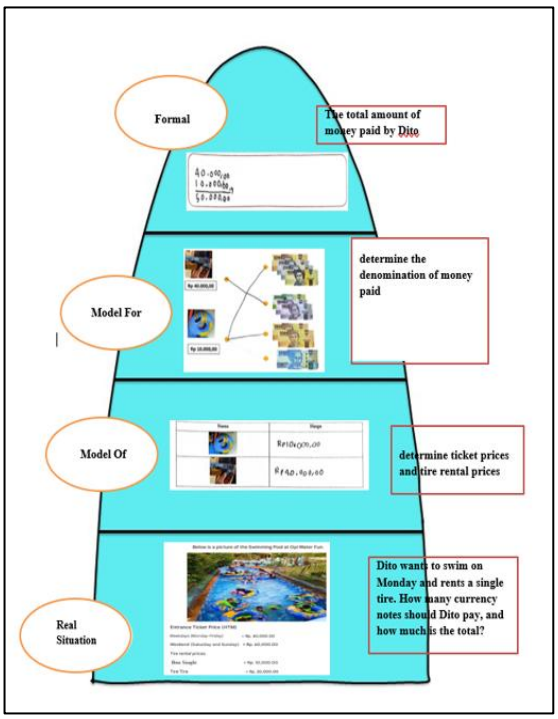

Figure 6. the iceberg of the value of money.

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Another important finding relates to the role of game rules in supporting autistic students' participation and thinking structure. The modified Monopoly game provided a sequence of predictable actions such as taking turns, rolling the dice, moving tokens, and responding to contextual prompts which appeared to create a comfortable learning rhythm for the students. This aligns with the characteristics of autistic learners who generally prefer routines, explicit expectations, and structured environments. The clear procedural rules reduced uncertainty and helped students maintain focus on the numerical tasks embedded within the game. This observation is consistent with the literature emphasizing that students with autism benefit from systematic instruction supported by step-by-step routines (Iovannone et al., 2003) and structured learning activities that promote engagement (Sabaruddin et al., 2020). Therefore, game-based learning does not merely serve as a contextual stimulus but also functions as a cognitive scaffold that aligns with autistic learners' need for predictability while gradually extending their participation in mathematical reasoning.

Several unique moments emerged during the lesson that reflected the typical characteristics of autistic students. For example, one student exhibited repetitive motor stimulation (hand flapping) when successfully counting the total amount of money correctly, which was interpreted as a non-verbal expression of joy. Students sought help by pinching the hands of other students when experiencing difficulties. Another student who was very fixated on one game square showed a strong interest in a particular object. These findings underscore the need for instructional flexibility in responding to non-verbal communication and interest preferences, which are very common in students with autism.

Overall, the results of implementing the learning trajectory through the "Let's Go Swimming" activity show that the contextual approach based on PMRI (Indonesian Realistic Mathematics Education) is highly effective in developing autistic students' understanding of the concept of money value. Through four gradual activities identifying the number of currency denominations, calculating the total value of money, recalculating item prices, and matching equivalent money values students demonstrated improved ability in recognizing and summing money values in a concrete manner.

The use of relevant contexts such as swimming at a pool, visual media like money images and price brochures, and manipulative tools such as a modified Monopoly board successfully facilitated meaningful learning (Babu et al., 2023). Furthermore, these activities not only developed basic mathematical skills but also encouraged social engagement and simple decision-making in real-life situations (Honorato et al., 2024). These findings reinforce that mathematics learning integrated with everyday experiences can provide equitable access for autistic students to understand the concept of money value and enhance their

active participation in the learning process (Mustafa & Maming, 2024).

IV. Conclusion

This study concludes that a PMRI-based learning trajectory delivered through swimming-themed activities on a modified Monopoly board effectively supports autistic students in understanding money value equivalence. Students showed noticeable improvement in recognizing denominations, calculating totals, and applying equivalence through visual and concrete media. However, the design appears most appropriate for autistic learners with moderate communication and cognitive profiles. Those with higher or lower support needs may require additional individual scaffolding or alternative approaches. Accordingly, special education teachers are encouraged to complement worksheets with concrete manipulatives and structured role-play scenarios to strengthen engagement and learning outcomes. This study is limited by its small sample size and single-site implementation, which may affect generalizability. Nonetheless, it contributes to mathematics education for autistic students by providing empirical evidence of contextual, game-based PMRI design and by underscoring the value of clear game rules. Future research could expand participants, include comparison groups, test other real-life contexts, or explore digital game environments.

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