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Engaging Minds, Fostering Behaviour: Interactive Mathematics Comic With Proton-Electron Media For Special Needs Students

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Abstract
Special needs students often face challenges in understanding mathematical concepts, which can impact both their learning outcomes and behavioural engagement. Incorporating interactive e-comics with proton-electron media may not only enhance their conceptual understanding but also influence their conceptual understanding of behaviour in mathematics. This study investigates whether using e-comics with proton-electron media improves the mathematics conceptual understanding of special needs students. Additionally, it examines their behaviour in solving mathematical conceptual tests. The sample was selected from public and private schools with similar student characteristics. Two students from each category—deaf, autistic, and intellectual disabilities—were selected based on their teachers' recommendations, ensuring they had similar abilities. A case study design was employed, using test questions and behaviour rubrics to assess conceptual understanding and behavioural patterns. Descriptive analysis was applied to compare students' behaviour before and after treatment. The findings indicate that students' mathematical understanding and behaviour vary significantly, making generalization difficult. While no changes in behavioural categories were observed across disabilities, an improvement in conceptual understanding was noted. Furthermore, the study identifies an additional behaviour pattern, semi-instrumentalist understanding behaviour, expanding on the findings of previous studies. These findings suggest that interactive e-comics with proton-electron media can be a valuable tool for enhancing the conceptual understanding of special needs students while offering educators insights into students' behavioural responses during learning.
Keywords: *Autism, Behavior, Deaf, Intellectual Disorder, Semi-Instrumentalist*

INTRODUCTION

One of the main goals of mathematics education is to develop students' knowledge and conceptualization and to establish connections between the two [1], [2], [3] . Knowledge refers to the utilization of dynamic rules or algorithms, which enables students to apply specific algorithms to relevant representations, while conceptualization encompasses both knowledge and skills, as well as proficiency in particular areas [4], [5]. Thes e two aspects play an important role in improving the quality and effectiveness of mathematics learning and teaching [6], [7]. In addition to these aspects, students must also be trained to develop a strong conceptual understanding of mathematics. According to Iannone and Cockburn, (2008)[1], [2], [3], mathematical conceptual understanding involves students engaging in mental interactions that facilitate the abstraction and generalization of concepts. Conceptual facts, concepts, principles, and algorithms are important for problem-solving [8], [9]. Therefore, teachers must be adequately prepared to provide innovative learning experiences and strong motivation, so that children can understand basic mathematics concepts effectively and meaningfully from an early age, particularly in elementary school [10], [11].

The most important concepts to teach in elementary school are addition and subtraction, as these concepts serve as fundamental building blocks for higher-level mathematics [12], [13], [14]. However, many problems occur when students try to understand this concept. According to [15], many studies show that most elementary school children under the age of 10 fail to use shortcut strategies to solve inverse problems such as "a + b − b", often relying on the use of "a + b − c" method. [16] found that

elementary school students frequently encounter difficulties in comprehending number values, place values, and operations involving numbers. [17] noted that students are accustomed to learning through the pattern a + b = □, which leads to difficulties when they encounter the pattern (a + □ = c) and the pattern (□ + b = c). Furthermore, elementary school students also struggle with fundamental concepts in addition and subtraction, such as the commutative, distributive, and associative properties [18]. Many studies have shown that in addition to difficulties in understanding the concepts of addition and subtraction, students also face challenges in solving mathematical problems related to these concepts [19], [20], [21], [22].

This problem also occurs among special needs students. These students often perform addition, subtraction, and number writing spontaneously, without fully understanding the operational forms involved in the problems [23]. Students with special needs may struggle to comprehend abstract terms and require substantial concrete experiences to grasp the concepts of addition and subtraction [24]. Another challenge faced by these students is a lack of confidence in developing their own strategies for applying the concepts of addition and subtraction in mathematical problem-solving [23]. Special needs students also have problems in choosing flexible strategies for solving addition and subtraction problems [25].

The difficulties faced by students with special needs in understanding the concepts of addition and subtraction can be attributed to the learning process often adhering strictly to prescribed solution methods. This approach may lead to errors, as it does not align with the students' own thinking but rather reflects the perspectives of the teacher or textbook author [26], [27], [28], [29]. Furthermore, students do not practice enough mathematics knowledge on addition and subtraction topics, which can be represented in at least three ways: procedural knowledge, which refers to computational skills; factual knowledge, which consists of memorized information about relationships between numbers; and conceptual knowledge, which involves understanding mathematics principles [6], [30], [31]. Special needs students do not yet have solid conceptual knowledge to determine whether they can choose to use the right concept to find and use strategies at the right time [24], [32]. The selected strategy cannot be used in a flexible and goal-oriented manner that influences and supports the selection and implementation of subsequent procedures in solving problems using the concepts of addition and subtraction by students [1], [33]. Furthermore, the use of mathematics procedures is not yet effective in carrying out operations determined by students when utilizing conceptual knowledge of addition and subtraction [17], [34], [35], [36].

Many researchers have tried to identify solutions to the challenges students face in understanding concepts related to addition and subtraction. Peters, et al (2014) [37] conducted a study aimed at teaching children with special needs by developing various flexible and diverse strategies for addition and subtraction. The results of his study indicate that the strategies developed for teaching children with special needs are more effective than traditional methods. Additionally, Polo-Blanco and González López (2021) [38] explored the development of informal strategies for problem-solving using the concepts of addition and subtraction among students with autism spectrum disorders. The results of this study indicate that students with autism disorders can represent answers in the correct form without any significant assistance. Furthermore, numerous mathematical learning media have been developed for students with special needs to address their learning difficulties. [39] developed a learning media called “Karbicus Media” to assist students with intellectual disabilities in understanding the concepts of addition and subtraction. The results of the study indicate that this media can effectively enhance students' abilities in adding numbers from 1 to 10. Additionally, research has also focused on the development of animated learning media, with findings suggesting that the developed media can be effectively utilized by students with special needs. [40] also utilized card media to enhance students' understanding of addition and subtraction concepts among deaf students. The results of his study demonstrate a significant improvement in the ability of deaf students to comprehend the concepts of addition and subtraction.

Furthermore, the Interactive Mathematics Comic with Proton-Electron Media is an innovative educational tool designed to enhance the conceptual understanding of addition and subtraction among students with special needs [41], [42]. By incorporating interactive storytelling, vibrant illustrations, and engaging animations, this medium simplifies complex mathematical concepts, making them more accessible and enjoyable [43]. The use of proton-electron media provides a unique representation of numerical values and operations, aiding students in concretely visualizing abstract ideas. Research suggests that visual and interactive learning approaches significantly enhance mathematical comprehension and

retention, particularly for students with learning difficulties [44], [45]. Additionally, integrating interactive elements into mathematical instruction has been shown to enhance students' motivation and confidence, resulting in improved learning outcomes [46]. Thus, the Interactive Mathematics Comic with Proton-Electron Media serves as an effective tool for fostering a deeper understanding of mathematics while making the learning process more engaging and inclusive.

Research has focused on improving the comprehension abilities of students with special needs regarding mathematical concepts in addition and subtraction. This research examines how students with special needs engage with the concepts of addition and subtraction. Conceptual understanding behavior encompasses the evaluation of students from various aspects, including cognitive, affective, and psychomotor domains. The assessment of conceptual understanding behavior is conducted using the Mathematics Concept Understanding Behavior Rubric, as outlined in the research by Gunawan et al., [47]. In the study, Gunawan et al., [47] categorized student behavior into three categories: instrumentalist, semi-relationalist, and relationalist. Students will be observed both before and after the intervention. The intervention involves a learning process utilizing a valid and practical e-comic with proton and electron media, which has been developed in previous research by Harisman et al., [41]. In addition to the teaching materials and strategies employed by teachers, the students' home or school environment will also influence their academic achievement [48], [49], [50]. This study examines the effectiveness of e-comics utilizing proton-electron media in enhancing the conceptual understanding of mathematics among students with special needs, and observes changes in their behavior when solving problems. The research questions addressed in this study are: (1) Does the use of e-comics with proton-electron media improve the mathematical conceptual understanding of students with special needs? and (2) Are there behavioral changes in problem-solving following the use of the learning media?

METHODS

This research is a follow-up study on the e-comic utilizing proton and electron media, which was developed in previous research [41]. Furthermore, this study examines the behavior related to the conceptual understanding of mathematics among students with special needs. The behavior of these students will be described both before and after the intervention. This section outlines the research design, participants, instruments, and data analysis.

Research Design

The research employed a case study design. Each subject's improvement was analyzed in terms of conceptual and behavioural understanding by comparing pre-test and post-test results. The study utilized classical analysis to describe the increase in each subject’s ability. The observed variables include the type of school (public and private) and three categories of special needs students: intellectual disabilities, deafness, and autism. The study examined students' conceptual understanding and behavioural engagement before and after the learning intervention, which integrates an interactive e-comic with proton-electron media for teaching addition and subtraction. The learning process was conducted by the researchers over four days using the e-comic, supported by special education teachers (SLB teachers) to ensure effective implementation.

Research Target/Subject

Research targets/subjects (for qualitative research) or sample-population (for quantitative research) need to be explained clearly in this section. It is also necessary to write down the technique of obtaining subjects (qualitative research) and/or the sampling technique (quantitative research).

Research Participant

The participants in the study consisted of six students from two special schools, including three students with different disabilities (deafness, intellectual disabilities, and autism) from a private school, and three students with the same disabilities from a public school. The selection of participants was based on the criteria that they came from the same educational level and possessed similar academic abilities. Participants were identified by teachers at the school, who referred to student performance in class. The sample size was determined using a purposive sampling technique, which is commonly employed in qualitative and small-scale experimental studies involving special [51]. Given the exploratory nature of this research, a small sample size is considered adequate for obtaining in-depth insights into the effectiveness of the intervention [52]. Previous studies indicate that research involving students with special needs often utilizes small sample sizes due to challenges in recruiting participants and the necessity for detailed individual observations [53]. Therefore, the selection of six participants ensures a manageable

yet diverse representation of students with different disabilities while maintaining the feasibility of data collection and analysis.

Instruments, and Data Collection Techniques

The research instrument used was a mathematics concept understanding test adjusted to the indicators of mathematics concept understanding ability and mathematics concept understanding behaviour. The mathematics conceptual understanding ability questions can be seen in Table 1.

Table 1. Mathematics Conceptual Understanding Questions

Number	Question
1	The sister exchanged his 5000 rupiah for 1000 and 2000 rupiah. How many 1000 and 2000 rupiahs did she get?
2	Read the story below and decide whether you will use addition or subtraction! Put a checkmark in one of the columns, addition or subtraction!
3	Dad bought 3 apples for Mom.  Mom also bought 2 apples; how many apples does Mom have now?
4	Bintang has Rp. 10,000. Because Bintang is a good sister, she gives Rp. 2,000 to Arkan and Rp. 3,000 to Nabila. How much money does Bintang have left?
5	In what activities can you use addition and subtraction?

Story	Addition	Subtraction
a. Arkan has Rp. 5,000. His uncle gave Arkan Rp. 10,000. How much money does Arkan have now?		
b. After receiving money from his uncle, Arkan bought fried food for 3000 rupiahs. How much money does Arkan have now?		
c. After Arkan bought fried food, Arkan found 2000 rupiah in his bag. How much money does Arkan have now?		

The test questions have been validated by four mathematics education experts. The validation results are presented in Table 2.

Table 2. Result of Mathematics Conceptual Understanding Questions Validation

Validator	Average Score	Category
Validator 1	4.4	Valid
Validator 2	4	Valid
Validator 3	5	Valid
Validator 4	3.6	Fair
Mean	4,25	Valid

In addition to assessing the ability to understand the concepts employed, students were interviewed regarding their mathematical responses to reveal their understanding behavior related to mathematical concepts. The reliability of the test is 0.74, indicating a fairly good level of consistency.

Data analysis technique

How to interpret the data obtained, in relation to the problems and research objectives, needs to be explained clearly.

The ability to understand mathematics concepts was assessed using the rubric in Table 3.

Table 3. Mathematics Conceptual Understanding Test Rubric.

Indicator	Score		
	0	1	2
Representing concepts in a different view	No answer	Has shown a way of thinking in stating concepts from different perspectives with few errors	Has shown a way of thinking in stating concepts from different perspectives correctly

Translating concepts in the verbal language into writing and vice versa	No answer	Has shown how to translate concepts from spoken to written and vice versa with minimal errors	Has shown how to translate concepts from spoken to written and vice versa correctly
Predicting trend patterns	No answer	Has shown how to predict pattern tendencies with minimal error	Has shown how to predict pattern tendencies correctly
Using the procedure skilfully.	No answer	Has shown how to use procedures with few errors	Has shown how to use procedures skilfully
Linking one concept with another	No answer	Has shown a slight error in connecting one concept to another	Has shown connecting one concept to another

Source: Gunawan et al. (2019)[47]

After the students' mathematics concept understanding ability has been scored with a rubric for each disability and each school, data processing was carried out using the Single Subject Research Technique to see whether e-comics affects the achievement of mathematics concept understanding abilities of special needs students. Furthermore, the behavior of students with each disability and from each school is classified and described based on the results of tests and interviews conducted with each student, utilizing the rubric presented in Table 4.

Table 4. Mathematics Conceptual Und erstand ng Behavior Rubric

Indicator	**Category**		
	Instrumentalist	**Semi relationalism**	**Relationalism**
Previous knowledge	Not utilizing prior knowledge	There is an attempt to utilize prior knowledge	Making use of prior knowledge
Representing concepts in a different view	Not being able to represent concepts from a different view	There is an error in representing a concept from a different point of view	Being able to represent a concept correctly from a different point of view
Translating concepts in the verbal language into writing and vice versa	Not being able to translate a concept into verbal or written language	There is an error in translating a concept into verbal or written language	Being able to translate a concept into verbal and written language
Predicts trend patterns	Not being able to predict the trend of a particular pattern	There is an error in predicting certain pattern trends	Being able to predict certain pattern trends
Using the procedure skilfully.	Not being able to use the procedure skilfully	There is a mistake in using the procedure	Being able to use the procedure skilfully
Linking one concept with another	Not being able to associate a concept with another concept	There is an error in associating a concept with another concept	Being able to link a concept with another concept
Metacognitive	Metacognitive thinking does not appear, either in written or verbal communication.	Metacognitive thinking appears verbally	Metacognitive thinking is evident in written and verbal responses
Belief	Unsure of his conceptual understanding	Being able to solve confidently some of the problems related to the concept he understands	Being confident in solving the problem related to the concept he understands
Confidence	Not confident	A little confident	Confident
Fast and precise	Slow in showing their understanding	Showing doubt in his or her understanding through answers to questions	Fast and precise in showing his

	through answers to questions	understanding through answers to questions

Source: Gunawan et al. (2019) [47]

RESULTS AND DISCUSSION

This section explains how special needs students behave before and after the learning process using e-commerce media assisted by protons and electrons on addition and subtraction topics. This section discusses how students understand mathematical concepts with their disability. How students behave before and after learning to use economic mathematics is explained in this section.

Changes in Mathematics Conceptual Understanding Ability

Data on students' pre-test and post-test improvement can be seen in Table 5.

Table 5. N-Gain Analysis of Conceptual Understanding Improvement Among Special Needs Students Using E-Comic with Proton-Electron Media

Disability	School	Student	Indicator	Pretest Score	Posttest Score	N-Gain Score
Intellectual Disorder	Public	PDT	1	0	0	0.00
			2	2	2	0.00
			3	2	2	0.00
			4	0	2	1.00
			5	0	0	0.00
	Private	PRI	1	0	2	1.00
			2	1	2	0.50
			3	2	2	0.00
			4	2	2	0.00
			5	0	0	0.00
Deaf	Public	DSS	1	0	0	0.00
			2	2	2	0.00
			3	2	2	0.00
			4	0	2	1.00
			5	0	0	0.00
	Private	MZM	1	0	2	1.00
			2	1	2	0.50
			3	2	2	0.00
			4	2	2	0.00
			5	0	2	1.00
Autism	Public	EZ	1	0	0	0.00
			2	2	2	0.00
			3	0	2	1.00
			4	0	0	0.00
			5	0	0	0.00
	Private	EPM	1	0	0	0.00
			2	0	0	0.00
			3	0	0	0.00
			4	0	0	0.00
			5	0	0	0.00

As Table 5 indicates, the N-Gain analysis of students' conceptual understanding and behaviour shows varying levels of improvement across different disabilities and school types. Students with intellectual disorders and hearing impairments from private schools demonstrated higher N-Gain scores, indicating a significant improvement in their understanding after the intervention. In contrast, students from public schools showed a range of high and low N-Gain values, suggesting that while some benefited from the learning process, others showed minimal progress. Notably, students with autism exhibited the lowest improvement, with many maintaining a pretest score of zero and showing no gains in the posttest. This suggests that the e-comic with proton-electron media is more effective for students with intellectual

disorders and hearing impairments but has a limited impact on autistic students. These findings highlight the need for tailored instructional strategies to better support students with different types of disabilities.

Changes in Mathematics Conceptual Understanding Behavior

This section explains how students with special needs behave when given a pretest or posttest regarding their ability to understand mathematical concepts. This behavior is described based on the Concept Understanding Behavior Rubric presented in Table 3. Student behavior was also analyzed by comparing public and private schools. The results were obtained by examining students' responses before and after the learning intervention, as shown in Table 6.

Table 6. Mathematics Conceptual Understanding Behavior

Type of Disability	School	Student	Pre-test	Postest
Intellectual Disorder	Public	PDT	Instrumentalist	Instrumentalist
	Private	PRI	Semi Relasionalist	Relasionalist
Deaf	Public	DSS	Instrumentalist	Instrumentalist
	Private	MZM	Instrumentalist	Relasionalist
Autism	Public	EZ	-	-
	Private	EPM	-	-

Instrumentalis

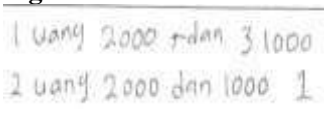
Instrumentalist behaviour is shown by PDT. PDT has an intellectual disorder and was given comprehension questions as outlined in Table 2. The following is a representation of PDT's responses to each conceptual comprehension question, along with the results of the interview with PDT. Figure 1 illustrates a representation of PDT's answers to question 1.

Figure 1. PDT's answer to Question 1

Translation
1000-rupiah bills

PDT answered question number one with 1000 rupiah bills. When asked why he answered 1000, PDT hesitated to answer and admitted that he did not understand the meaning of the question. PDT also stated that the answer was obtained by guessing. When given directions to use real money, PDT was able to give the right answer and responded in a different perspective which can be seen in Figure 2.

Figure 2. PDT's answer to Question 1 in Interview

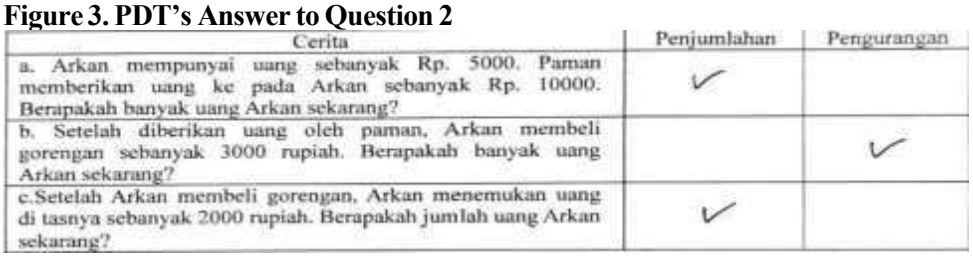


Tranlation
One 2000-rupiah bill and three 1000-rupiah bills
Two 2000-rupiah bill and one 1000-rupiah bills

PDT can provide two perspectives: if there are one or two thousand rupiah bills and three one-thousand rupiah bills, PDT can respond with two two-thousand rupiah bills and one one-thousand rupiah bill. PDT demonstrates metacognition in oral communication. Although PDT appears hesitant in responding, he exhibits a degree of confidence when answering questions.

The representation of PDT's answer to Question 2 is shown in Figure 3.

Figure 3. PDT's Answer to Question 2



Cerita	Penjumlahan	Pengurangan
a. Arkan mempunyai uang sebanyak Rp. 5000. Paman memberikan uang ke pada Arkan sebanyak Rp. 10000. Berapakah banyak uang Arkan sekarang?	✓	
b. Setelah diberikan uang oleh paman, Arkan membeli gorengan sebanyak 3000 rupiah. Berapakah banyak uang Arkan sekarang?		✓
c.Setelah Arkan membeli gorengan, Arkan menemukan uang di tasnya sebanyak 2000 rupiah. Berapakah jumlah uang Arkan sekarang?	✓	

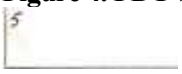
Tranlations

Story	Addition	Subtraction
a. Arkan has Rp. 5,000. Uncle gave Arkan Rp. 10,000. How much money does Arkan have now?	v	
b. After being given money by his uncle, Arkan bought fried food for 3000 rupiahs. How much money does Arkan have now?		v
c. After Arkan bought fried food, Arkan found 2000 rupiah in his bag. How much money does Arkan have now?	v	

As Figure 3 indicates, for question 2, PDT was able to identify the pattern tendency; how0ever, when asked again, PDT seemed hesitant to respond. PDT admitted that for answer number 2, he only guessed. When given guidance to use money again, PDT was able to answer the question correctly. PDT determined that in story A, Arkan's money was fifteen thousand; in story B, it was twelve thousand; and in story C, it was only fourteen thousand. When determining the story, PDT remained uncertain about the addition or subtraction of some of the answers provided.

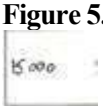
PDT's answer to Question 3 can be seen in Figure 4.

Figure 4. PDT's answer to Question 3



PDT answered correctly to Question 3, and when explaining verbally, he was able to articulate his answer, albeit with some hesitation. Although PDT remains uncertain about his abilities, he demonstrated a degree of confidence in explaining Question 3. He employed the correct procedure, specifically adding apples. In contrast, for Question 4, PDT made errors in his response. A representation of PDT's answer to Question 4 is illustrated in Figure 5.

Figure 5. PDT's answer to Question 4



When asked why he wrote the number fifteen thousand in his answer, PDT regarded the problem as an addition problem. This indicates that PDT still does not fully understand the problem and continues to have difficulty distinguishing between addition and subtraction. However, when tested with real money, PDT was able to arrive at the correct answer. He successfully employed the appropriate procedure in solving Question 4 with the assistance of money. A representation of PDT's answer can be seen in Figure 6.

Figure 6. PDT's answer to Question 4 in the interview

Next, PDT's answer to Question 5 can be seen in Figure 7.

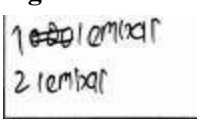
Figure 7. PDT's answer to Question 5

When asked for the answer to Question 5, PDT admitted to responding by guessing. He appeared to remain uncertain about the concepts of subtraction and addition. PDT has not been able to utilize prior knowledge and cannot connect one concept to another. Therefore, PDT can be categorized as exhibiting instrumentalist behavior.

Semi-Relasionalist

PRI showed semi-relationalist behavior. PRI has an intellectual disorder and a semi-relational behaviour category. The following is PRI's answers for each conceptual understanding question and the results of the interview with PRI. Figure 8 shows a representation of PRI's answers to Question 1.

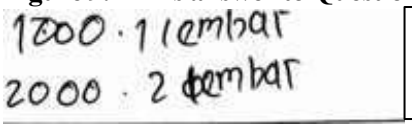
Figure 8. PRI's answer to Question 1



Tranlations
1 sheet
2 sheets

PRI answered Question 1 with the response of 1 sheet and 2 sheets, which is unclear. When asked why he provided the answers of 1 sheet and 2 sheets, PRI explained that he meant 1 sheet of one thousand rupiah and 2 sheets of two thousand rupiah. From this response, PRI has demonstrated the ability to articulate the concept from a different perspective. He is confident, quick, and responsive in demonstrating his understanding when answering questions. Improvements in PRI's responses can be seen in Figure 9.

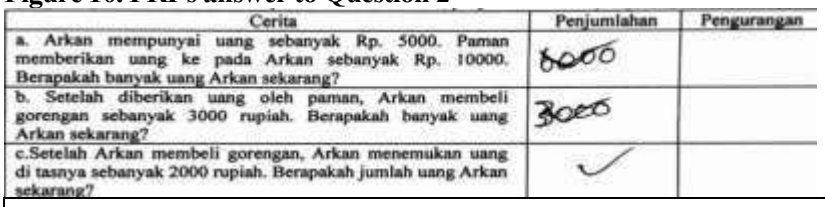
Figure 9. PRI's answer to Question 1 in interview



Tranlations
One 1000-rupiah bill
Two 2000-rupiah bill

Furthermore, the representation of PRI's answer to Question 2 can be seen in Figure 10.

Figure 10. PRI's answer to Question 2



Cerita	Penjumlahan	Pengurangan
a. Arkan mempunyai uang sebanyak Rp. 5000. Paman memberikan uang ke pada Arkan sebanyak Rp. 10000. Berapakah banyak uang Arkan sekarang?	5000	
b. Setelah diberikan uang oleh paman, Arkan membeli gorengan sebanyak 3000 rupiah. Berapakah banyak uang Arkan sekarang?	3000	
c.Setelah Arkan membeli gorengan, Arkan menemukan uang di tasnya sebanyak 2000 rupiah. Berapakah jumlah uang Arkan sekarang?	✓	

Tranlations

Story	Addition	Subtraction
a. Arkan has Rp. 5,000. Uncle gave Arkan Rp. 10,000. How much money does Arkan have now?	v	
b. After being given money by his uncle, Arkan bought fried food for 3000 rupiahs. How much money does Arkan have now?	v	
c. After Arkan bought fried food, Arkan found 2000 rupiah in his bag. How much money does Arkan have now?	v	

From Figure 11, two PRIs were able to identify the pattern tendency; however, there are errors in story part B. When asked again, PRI can correctly identify the story that involves both addition and subtraction. PRI is quick and responsive in demonstrating understanding when answering questions. Metacognition is evident in PRI's speech and writing; in his written response, PRI modifies the answer that was previously the result of the operation by marking it with a check. During the interview, PRI corrects his answer, as illustrated in Figure 11.

Figure 11. PRI's answer to Question 3

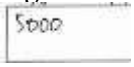
Cerita	Penjumlahan	Pengurangan
a. Arkan mempunyai uang sebanyak Rp. 5000. Paman memberikan uang ke pada Arkan sebanyak Rp. 10000. Berapakah banyak uang Arkan sekarang?	5000	
b. Setelah diberikan uang oleh paman, Arkan membeli gorengan sebanyak 3000 rupiah. Berapakah banyak uang Arkan sekarang?	3000	✓
c.Setelah Arkan membeli gorengan, Arkan menemukan uang di tasnya sebanyak 2000 rupiah. Berapakah jumlah uang Arkan sekarang?	✓	

Tranlations

Story	Addition	Subtraction
a. Arkan has Rp. 5,000. Uncle gave Arkan Rp. 10,000. How much money does Arkan have now?	v	
b. After being given money by his uncle, Arkan bought fried food for 3000 rupiahs. How much money does Arkan have now?	v	v
c. After Arkan bought fried food, Arkan found 2000 rupiah in his bag. How much money does Arkan have now?	v	

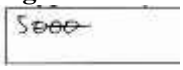
The representation of PRI's answer to Question 3 can be seen in Figure 12.

Figure 12. PRI's answer to Question 4



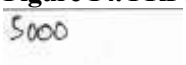
From Figure 12, PRI made a mistake in answering the question; however, upon repeating the question, PRI was able to answer correctly. He successfully employed the appropriate procedure in solving Question 3. The previous error was attributed to PRI's carelessness, as he did not focus on the specifics of Question 3. While PRI is confident in his abilities, he has demonstrated assurance in explaining Question 3. PRI understands that the key to Question 3 involves buying food, and he added an apple in his response. The following is PRI's corrected answer for Problem Number 3, which can be seen in Figure 13.

Figure 13. PRI's answer to Question 3 in interview



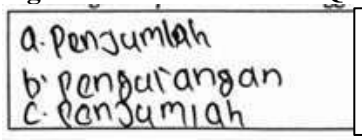
Meanwhile, for Question 4, PRI was able to answer the question correctly. The following is a representation of PRI's answer to Question 4 which can be seen in Figure 14.

Figure 14. PRI's answer to Question 4



PRI skillfully employed the procedure in Question 4. He explained that the money given to Arkan is two thousand, and the amount given to Nabila is three thousand, leaving Bintang with only five thousand. PRI recognized that this problem involves subtraction, as money is given to both Arkan and Nabila. He also demonstrated an effort to utilize prior knowledge. PRI's answer representation for Question 4 can be seen in Figure 15.

Figure 15. PRI's answer to Question 5



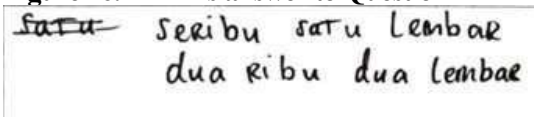
Tranlations
a. Addition
b. Subtraction
c. Additiona

When asked for the answer to Question 5, PRI responded by indicating addition, subtraction, and addition again. PRI stated that his response to Question 5 was based on the activities described in Question 2. From this answer, PRI demonstrated the ability to distinguish between addition and subtraction activities. However, he remained hesitant to provide examples of daily life activities related to Question 5. PRI also attempted to utilize prior knowledge to answer Question 5. Based on the results of these responses, PRI can be categorized as exhibiting relationalist behavior.

Relasionalist

The behavior exhibited by MZM after participating in the learning process with the e-comic demonstrates characteristics of the relationalist behavior category. Almost all of MZM's answers were correct. Figure 16 illustrates the representation of MZM's responses to Question 1.

Figure 16. MZM's answer to Question 1



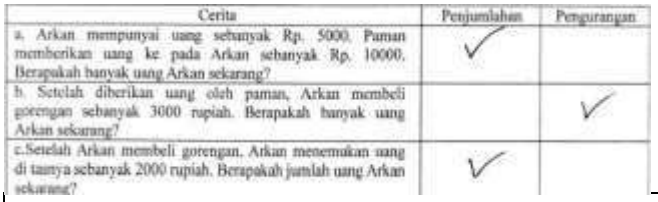
Tranlations
One 1000-rupiah bill
Two 2000-rupiah bill

MZM was able to answer this question correctly from one perspective. When asked whether there were other possible answers to Question 1, MZM appeared somewhat hesitant and confused. The researcher then presented 5000, 1000, and 2000 rupiah bills and asked MZM to explore other possibilities based on the answers previously given. MZM successfully identified alternative perspectives by providing examples. Figure 17 illustrates a representation of MZM's responses when the money denominations were presented.

Figure 17. MZM's answer to Question 1 in the interview

In Figure 17, it can be observed that MZM is able to present an alternative perspective using 2000 and 1000 rupiah denominations, specifically by indicating that there are 3 one-thousand notes and 2 two-thousand notes. When explaining, MZM demonstrates a clear understanding and exhibits confidence in delivering the answer. The following is a representation of MZM's response to Question 2, which can be seen in Figure 18.

Figure 18. MZM's answer to Question 2



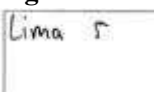
Cerita	Penjumlahan	Pengurangan
a. Arkan mempunyai uang sebanyak Rp. 5000. Paman memberikan uang ke pada Arkan sebanyak Rp. 10000. Berapakah banyak uang Arkan sekarang?	✓	
b. Setelah diberikan uang oleh paman, Arkan membeli gorengan sebanyak 3000 rupiah. Berapakah banyak uang Arkan sekarang?		✓
c.Setelah Arkan membeli gorengan, Arkan menemukan uang di tanya sebanyak 2000 rupiah. Berapakah jumlah uang Arkan sekarang?	✓	

Tranlations

Story	Addition	Subtraction
a. Arkan has Rp. 5,000. Uncle gave Arkan Rp. 10,000. How much money does Arkan have now?	v	
b. After being given money by his uncle, Arkan bought fried food for 3000 rupiahs. How much money does Arkan have now?		v
c. After Arkan bought fried food, Arkan found 2000 rupiah in his bag. How much money does Arkan have now?	v	

For Question 2, MZM was able to identify the pattern tendency. When asked, MZM demonstrated a clear understanding of the problem and was able to provide the correct rationale by identifying the keywords: if money is given, then addition is required; if something is purchased, it will reduce the available funds. MZM answered with full confidence. Furthermore, for Question 4, MZM successfully applied the correct procedure in his response. Additionally, MZM answered the questions in Question 3 effectively. Figure 19 illustrates the representation of MZM's answers.

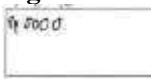
Figure 19. MZM's answer to Question 3



Tranlations
Five 5

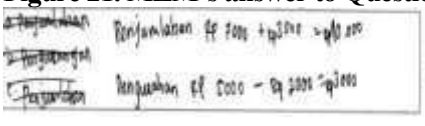
As shown in Figure 20, MZM's answer is correct. MZM also provides justifications and demonstrates the procedure accurately, stating that the number of apples increases because of the phrase "given by Mother." He answered with confidence. However, when asked if he had encountered a similar problem before, he did not understand the question and was unable to provide an example of a prior experience. Furthermore, for Question 4, MZM was also able to answer correctly. The representation of MZM's answer can be seen in Figure 20.

Figure 20. MZM's answer to Question 4



In Question 5, MZM correctly identified the procedure, subtracting the original amount of money from the amounts given to his two siblings. MZM was also able to explain the problem clearly and confidently. When the researcher inquired why he subtracted the money, MZM responded that it was because the funds were given to Arkan and Nabila. Furthermore, MZM successfully related the problem to other concepts, specifically everyday life situations, and provided examples of addition and subtraction, as illustrated in Figure 21.

Figure 21. MZM's answer to Question 4



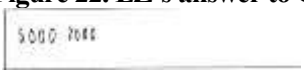
Tranlations
Addition: Rp 7000 + Rp 3000 = Rp 10.000
Subtraction: Rp 5000 – Rp 2000 = Rp 3000

In the interview, MZM provided examples of addition, stating that it occurs when he is given money or finds money in a bag, cupboard, or on the street. He also noted that subtraction is applicable when he purchases food with his money or gives the money he has to his younger or older siblings. MZM demonstrates strong self-confidence. His metacognitive thinking is evident in both oral and written communication; in his written responses, MZM crossed out incorrect answers before arriving at the correct one. He mentioned that initially, he considered Question 2 while attempting to answer Question 5, but upon rereading the question, he realized that it required him to provide examples of addition and subtraction problems. Based on MZM's responses, he can be categorized as exhibiting relationalist behavior.

Behavior that cannot be categorized based on expert rubrics

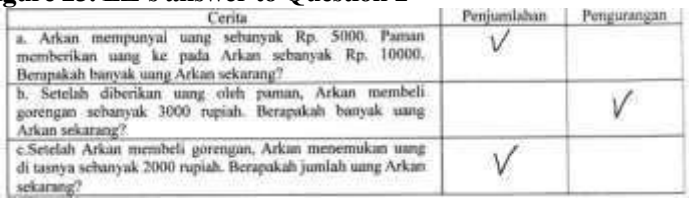
From the tests and interviews conducted, it was found that EZ could not be categorized within the mathematics concept understanding behavior rubric. This applies to all existing indicators, with the exception of the "prior knowledge" indicator, where EZ demonstrated some understanding of addition and subtraction involving integers. In terms of prior knowledge, EZ is able to recognize and identify numbers, although errors are present. For instance, when reading the number 1000, he misreads it as "ten thousand" in Question 1, as illustrated in Figure 22.

Figure 22. EZ's answer to Question 1



When the interviewer asked EZ to read the number again, he still misread it as "ten thousand." This indicates a lack of metacognitive awareness in EZ. Furthermore, EZ is unable to extract information from the reading text, as evidenced by the responses he provided. During the interview, EZ tended to focus solely on identifying the numbers, resulting in answers such as "5000" and "2000," which merely repeated the numerical information presented in the question without considering the accompanying context or sentences. Ultimately, when asked to explain what the question was asking, EZ was unable to provide a response and simply reread the question. The interviewer continued to inquire about EZ's answer to Question 2. Interestingly, for Question 2, EZ was able to answer correctly. EZ's response to Question 2 can be seen in Figure 23.

Figure 23. EZ's answer to Question 2



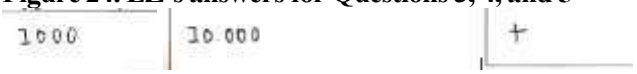
Cerita	Penjumlahan	Pengurangan
a. Arkan mempunyai uang sebanyak Rp. 5000. Paman memberikan uang ke pada Arkan sebanyak Rp. 10000. Berapakah banyak uang Arkan sekarang?	√	
b. Setelah diberikan uang oleh paman, Arkan membeli gorengan sebanyak 3000 rupiah. Berapakah banyak uang Arkan sekarang?		√
c.Setelah Arkan membeli gorengan, Arkan menemukan uang di tasnya sebanyak 2000 rupiah. Berapakah jumlah uang Arkan sekarang?	√	

Tranlations

Story	Addition	Subtraction
a. Arkan has Rp. 5,000. Uncle gave Arkan Rp. 10,000. How much money does Arkan have now?	v	
b. After being given money by his uncle, Arkan bought fried food for 3000 rupiahs. How much money does Arkan have now?		v
c. After Arkan bought fried food, Arkan found 2000 rupiah in his bag. How much money does Arkan have now?	v	

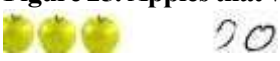
However, when asked, EZ was unable to explain how he arrived at his answer for this question. The interviewer suspected that EZ remembered this question from a previous meeting, during which it had been tested with the assistance of the teacher. In this instance, the interviewer chose not to pursue further questions, as EZ could not articulate how he reached his answer. Furthermore, for Questions 3, 4, and 5, EZ was also unable to process the available information. He struggled to comprehend the questions, and at times, his responses were completely unrelated. EZ's answers to Questions 3, 4, and 5 can be seen in Figure 24.

Figure 24. EZ's answers for Questions 3, 4, and 5



In question number 3, EZ answered with the number 1000 which does not correlate with the question given. For this question, the interviewer tried to provide a picture of 2 more apples. These additional 2 apples can be seen in Figure 25.

Figure 25. Apples that were added by the interviewer



When the interviewer asked EZ again, "How much is this?" EZ responded with "5." In Question 4, EZ followed the same pattern as in Question 1, where he merely recorded the numerical information provided in the question without attending to or understanding the context or the question itself. For Question 5, EZ also demonstrated a lack of comprehension and chose to write the "+" sign, which represents the addition operation. In this assessment, EZ exhibited behaviors that do not align with the appropriate mathematics concept understanding behavior rubric. His responses indicated that he had not effectively processed the information, rendering him unable to respond to literacy questions. This was further supported by the observation that he could only answer questions related to contexts that were

directly visible, without any accompanying textual information, as illustrated in Figure 31. EZ's behavior is summarized in Table 4, and a detailed description of his behavior can be found in Table 7. In this research, EZ is classified as exhibiting semi-instrumentalist behavior.

Table 7. Behavior that cannot be categorized based on expert rubrics

Indicator	**Category**
	Semi Instrumentalist
Previous knowledge	Not focusing/paying attention to learning utilizing prior knowledge.
Represents concepts in a different view	Not focusing/paying attention to learning to represent concepts from a different view.
Translating concepts in the verbal language into writing and vice versa	Not focusing/ paying attention to learning to translate a concept into verbal or written language
Predicts trend patterns	Not focusing/ paying attention to learning to predict the trend of a particular pattern.
Use the procedure skilfully.	Not focusing/ paying attention to use the procedure skilfully.
Linking one concept with another	Not focusing/ paying attention to associate a concept with another concept.
Metacognitive	Not focusing/ paying attention to Metacognitive thinking either in written or verbal communication.
Belief	Not focusing/ paying attention to conceptual understanding.
Confidence	Just looking left and right and not paying attention.
Fast and precise	Not Paying attention

Based on the research results, it is evident that some factors impact student behavior, while others do not influence their understanding of concepts. For students with intellectual disabilities in both public and private schools, the behavioral categories they exhibit remain consistent; however, there may be slight shifts in their understanding of the material being studied. Children with intellectual disabilities learn at their own pace [54], [55]. Nevertheless, they must interact with peers and their environment, allowing them to learn together in a shared space, albeit with varying depths and breadths of understanding.

Based on the learning process, several aspects must be clarified in economic mathematics assisted by protons and electrons, including: (1) clarifying the use of brackets, particularly in subtraction operations involving subsequent numbers; and (2) elucidating the meaning of the number zero, specifically in the context of combining red and blue pieces. This clarification is essential to ensure that students do not hesitate to incorporate the number zero during subtraction operations when there are insufficient colored pieces or when they do not realize that pieces have been removed. The effectiveness of the learning process is contingent upon how teachers develop learning tools. If educators create effective learning tools, students are more likely to engage positively in the learning process. Competent educators emerge from well-prepared teachers in the learning environment [56]. Student behavior can also be influenced by the integration of various engaging teaching materials and resources [56], [57], [58], [59], [60], [61], [62], [63], [64], [65]. The findings of this study highlight the potential benefits of integrating interactive e-comics with proton-electron media into mathematics instruction for students with special needs. Given that these students often struggle with abstract mathematical concepts [66], interactive and visually engaging tools can serve as effective learning aids, enhancing both their conceptual understanding and problem-solving behaviors. The study's identification of variations in students' mathematical comprehension and behavioral engagement highlights the necessity for a more personalized learning approach, consistent with prior research that emphasizes individualized instruction to address diverse learning needs [67]. Furthermore, the recognition of a semi-instrumentalist understanding of behavior contributes to existing theoretical frameworks, providing educators with deeper insights into how students with special needs process mathematical information. These findings suggest that teachers and curriculum developers should incorporate digital learning tools to enhance accessibility and engagement in mathematics education [68]. Additionally, teacher training programs should integrate strategies for utilizing multimedia resources, as research has demonstrated that technology-enhanced learning environments can significantly improve academic performance and motivation among students with special needs[69]. While challenges remain

in generalizing these results, the study reinforces the importance of interactive digital tools in fostering mathematical understanding and adapting teaching strategies to accommodate diverse learning abilities.

CONCLUSIONS

Students with three disabilities, which are deafness, intellectual disorder, and autism, demonstrated an increase in their ability to understand mathematical concepts, with the exception of one student with autism who was unable to complete the test or engage in the learning process due to an unstable mental state. The behavior of the three students from the three schools exhibited positive changes; although there was no alteration in the behavioral category associated with each disability, there was a notable increase in their understanding of the concepts presented. In the case of autistic students, behavior cannot be adequately defined using the behavioral rubric established by previous researchers. Therefore, in this study, we propose a new category of behavior termed "semi-instrumentalist."

One limitation of this study is the difficulty in generalizing the findings due to the small sample size and the diversity of special needs conditions among participants. Since only two students from each category were included, the results may not fully represent the broader population of students with special needs. Additionally, while the study identifies improvements in conceptual understanding, the lack of significant changes in behavioral categories suggests that other factors, such as prior learning experiences or external support, may influence students' engagement. The study also relies on a descriptive analysis approach, which, while valuable for understanding individual behavioral patterns, limits the ability to establish causal relationships between the use of interactive e-comics and students' learning outcomes. Furthermore, the study does not account for the long-term retention of mathematical concepts, raising questions about the sustainability of the observed improvements. Future research should consider larger, more diverse samples and employ longitudinal studies to assess the lasting impact of interactive e-comics on the learning and problem-solving behaviors of students with special needs[70], [71], [72], [73], [74].

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Conflict Of Interest

The author declares that there is no conflict of interest.

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