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THE DEVELOPMENT OF PROTON-ELECTRON MATH E-COMIC TO IMPROVE SPECIAL NEEDS STUDENTS' MATHEMATICAL CONCEPTS UNDERSTANDING

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ABSTRACT

Technology-based learning media is still lacking for special needs students in mathematics. Based on observations and interviews with Special School (SLB) teachers, the learning media used were still monotonous, such as picture books and writing using a blackboard. This research aims to develop e-comic math using the App Pixton application, which is valid and practical for children with special needs in SLB. The research method used is Plomp model development research in the prototype development phase: self-evaluation, expert review, and one-to-one evaluation. The data collection instruments used were a questionnaire and mathematical concepts on addition and subtraction topics for students with special needs. The research subjects were 21 students and 5 teachers from 5 different special schools in 5 West Sumatra, Indonesia cities. The study results show that the media developed is valid and practical for students with deaf and intellectual disabilities. This research implies that teachers must be able to develop other IT-based learning media to help students with special needs learn mathematics like normal children.

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1. INTRODUCTION

Nowadays, the learning media should be technology-based so that it is attractive to students (Hidayat et al., 2022; Hidayat et al., 2023; Motta et al., 2020). This situation means that teachers must master various applications to actualize it. For example: developing learning media using GeoGebra, Adobe Acrobat, and Kvisoft Flipbook Maker (Augustha et al., 2021; Jelatu et al., 2018; Wibowo & Pratiwi, 2018; Zetriuslita et al., 2020).

In reality, it is just a few of technology-based learning media developed by teachers for the learning process (Hidayat & Aripin, 2023; Winda & Dafit, 2021; Wulandari et al., 2020). This situation is because of: 1.) Teacher do not master the ability to develop technology-based media, 2.) Lack of facilities such as: internet and projector, 3.) Lack of time (Muhazir & Retnawati, 2020).

The lack of technology-based learning media is also a problem in students with special needs mathematics learning. The media that is still lacking for students with special needs are: 1.) Learning videos; 2.) Game-based learning media that is attractive to students; and 3.) Software-based media (Cagiltay et al., 2019). Based on observations and interviews, the problem is also appear. Teacher said that the learning media used were still monotonous, such as drawing numbers with crayons on a picture book and writing using a blackboard. Teacher also said that special needs students should have an introduction, assistance, and the use of technology-based media in the learning process (Ayuningtyas & Sevilla, 2020). Furthermore, based on a survey of 100 teachers who teach in special schools, 70 percent of teachers stated that material and concepts that are difficult to teach to children with special needs are addition and subtraction (Ebby et al., 2020). The difficulties of students with special needs in addition and subtraction are: misconceptions about operations involving zero, not yet mastering the procedure for adding numbers by saving and subtracting numbers by borrowing; difficulty interpreting story problems; and lack of accuracy in working on questions. Roy (2014) also found various difficulties experienced by students with special needs in understanding addition and subtraction material are: (1) students find it difficult to recognize the signs on the numbers being operated, (2) students find it difficult to recognize operations on addition and subtraction, (3) students have difficulty concentrating in learning, and students are less interested in the learning process. Children always interpret what is close to them. Like the plus and minus symbols in number operations, students will better understand the meaning that is close to their world, such as two oranges added with two oranges and other examples (Asuncion et al., 2012; de Mesquita, 2004; Harisman, Noto, Hidayat, et al., 2021).

Various ways can be done by the teacher in developing the ability to understand concepts in addition and subtraction material for students with special needs. One way to develop students' conceptual understanding skills in addition and subtraction operations is to provide practice, use suitable media, provide reinforcement with contextual problems that are close to the student's world, and use a number base (Hardianti & Zulkardi, 2019; Kullberg et al., 2020; Sahat et al., 2018). Rahmasantika and Prahmana (2022) research also tried to develop e-comics for special school students, as this study has been developing Math e-Comic with an ethnomathematics context, namely the Folklore "Joko Kendil and Si Gundul" to develop the critical thinking skills of deaf students. In the results of his research, the product developed can improve the critical thinking skills of deaf students. Furthermore, Hartati's research has also developed e-comics to improve the reading ability of deaf students (Hartati et al., 2023). This media is also effective on the math reading skills of deaf students.

This research is different to other researches, not only combined with proton – and electron media (colored chips), this research is also have big scale, which is West Sumatera. This research purpose is to develop e-comic math using the Pixton App. In comics, theme-based storylines are created such as at school, in the mountains, and at the beach. For addition and subtraction operations in comic stories, proton, and electron media are used (color keeping). Furthermore, it is seen how the validity and practicality of this media in children with special needs in special schools.

2. METHOD

The research method used is Plomp model, which is prototyping phase (Plomp, 2013). The process of this prototyping phase started with developing math e-comic based on the preliminary research which has been written in another paper. The design results at this stage are called prototype 1. After the prototype 1 is ready, the development phase is started with self-evaluation, expert review, one-to-one evaluation, small group evaluation, and field test. This article will only describe expert review and one-to-one evaluation. The process can be seen in Figure 1.

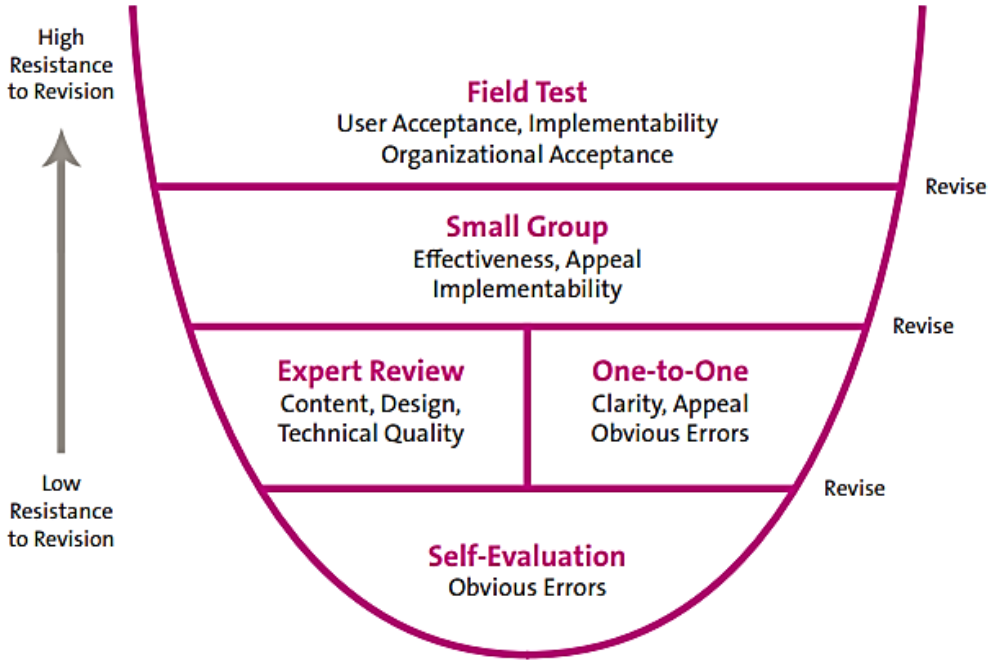


Figure 1. Formative evaluation (Plomp, 2013)

2.1. Expert Review

The expert assessment aims to validate the product by providing assessments and advice according to the expert's field. The validators involved were five people consisting of three mathematics education experts, one language expert, and educational technology.

2.2. One-to-One Evaluation

In the one-on-one evaluation, it is carried out by asking for suggestions from users that already use the protoypte, namely a teacher and three students. Learners are selected based on high, medium, and low ability levels. The purpose of this individual evaluation is to identify possible errors contained in the Math e-comic Assisted by the Pixton App in the form of material, implementation, and to see the technical quality and practicality of the product. For this phase, it was carried out at 5 Special Schools (SLB) in West Sumatra by taking 4-5 students and 1 class teacher each school.

3. RESULT AND DISCUSSION

3.1. Results

Based on the results of preliminary analysis at 5 special schools in West Sumatra, a mathematical e-comic was developed on addition and subtraction topic with the help of proton and electron media. The e-comic elements that are developed consist of covers, learning objectives, material with natural contexts and places as well as proton and electron media assistance (colored chips), and practice questions.

The cover is designed simply and is colored green, blue, and gray according to the colors the students like and the validator's suggestions. On the cover with the theme of nature where you can see the sky, clouds, trees, and children playing in the park. The book contains the identity the title and the name of the author. The results of the cover have been revised several times, after it is believed that it is good enough to contain all the information needed, the cover is obtained in Figure 2.

Figure 2. Mathematics e-comic's cover

It is hoped that the cover color in Figure 2 is bright and the location of the playground can make students enthusiastic about learning.

Learning objectives describe the goals to be achieved for each topic. These goals are made in the form of comic characters with attractive designs shown in Figure 3.

Figure 3. Mathematics e-comic's learning objectives

In Figure 3 it can be seen that there are three learning objectives, namely the addition of positive integers with positive, positive with negative, and negative with negative reducing positive integers with positive, positive with negative, and negative with negative, as well as solving problems in everyday life that involve adding and subtracting positive and negative numbers correctly.

The character introduction part in e-comics is introducing the characters in e-comic stories. The characters in the e-comic consist of female teachers, male teachers, female students, male students, canteen keepers, fruit sellers, and school security guards as shown in Figure 4.

Figure 4. Mathematics e-comic's characters

In Figure 4 all the characters introduce their names and play their roles in the economic story.

The learning process consists of three parts, namely addition, subtraction, and solving problems related to addition and subtraction. The situation addition material displayed is the beach situation shown in Figure 5.

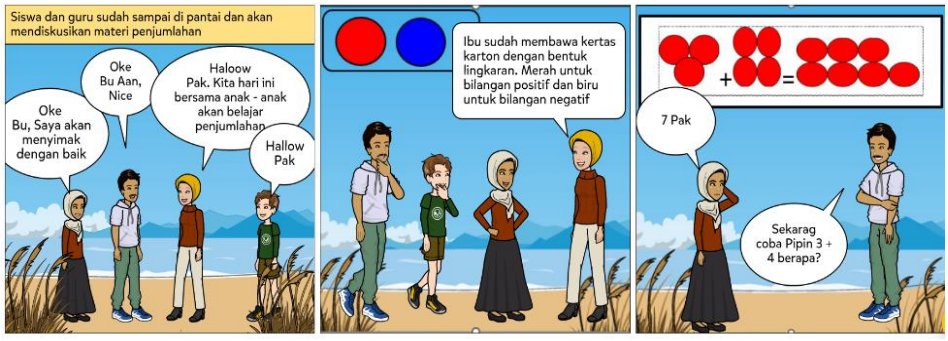


Figure 5. "Addition" learning process

In Figure 5 you can see the teacher and student interaction, where the teacher gives problems regarding addition operations and students answer using the help of protons and electrons media.

For the subtraction learning process, the expected situation is hiking to the mountain that can be seen in Figure 6.

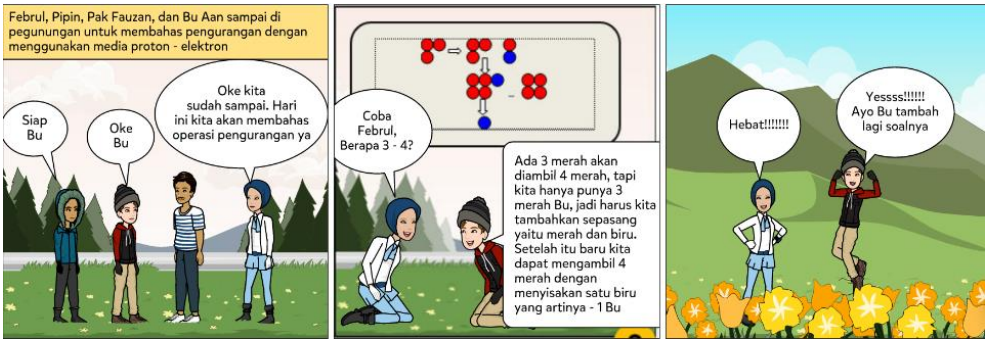


Figure 6. "Subtraction" learning process

Figure 6 also shows the interaction between the teacher and students, where the teacher gives problems regarding subtraction operations, and students answer using the help of protons and electrons.

Furthermore, for solving problems related to adding and subtracting the situations shown are the situation of schools and school canteens as shown in Figure 7.

Figure 7. "Aplication of addition and subtraction" learning process

In Figure 7 it can be seen that the problem is given by giving a contextual problem of buying fruit and other goods involving school elements such as security guards, canteen mothers, and so on.

Practice questions are given at the end of the learning process presented by the characters and shown in Figure 8.

Figure 8. Mathematics e-comic's practice

In Figure 8, additional questions are given to students to make them able to practice the material that has been given

3.1.1. Validity

Expert Review

The aspects that are assessed in the expert validation are aspects of content, language, and graphics or appearance. The validation results are presented in Table 1.

Table 1. Mathematics e-comic's validity

Aspects	Validity Average (%)	Criteria
Content	94.2	Very Valid
Language	85.6	Very Valid
Graphics or Display(Multimedia)	93.8	Very Valid
Average	91.2	Very Valid

Based on Table 1, it can be seen that the e-comic assisted by Pixton and help of proton electron is very valid. All aspect, which is content, language, and display is also very valid and the prototype will continue to the next step of phase. Furthermore, there are also several suggestions to make the product better. The suggestions are presented in Table 2.

Table 2. Expert review suggestion and revision

Suggestions	Revision	
	Before	After
Content		
Provide pages, so that they can be read sequentially	There are no page numbers on e-comic yet	Has given the page numbers on e-comics
There are parts of the comic that are out of order	The third row in the first column should be in the second row in the first column. The order of the comic story is reversed.	The conversation order has been adjusted according to the validator's requirements
Also define the meaning of + - as operations	No sign of operation on addition of protons-electrons	Already added the sign of the addition operation on the protons-electrons
Add word problems about negative numbers	There were no scenarios regarding applications in everyday life that discussed negative numbers	Adding story problem scenarios about negative numbers with the context of temperature in classroom situations.
There's still a typo, check again	Validator circling the	Fixed all the typos

Suggestions	Revision	
	Before	**After**
	typo on product	suggested by the validator
Language		
Simplify sentences	As in that part, there are 3 reds and 4 reds will be taken. Looks like the sentence editor can still be changed, for example, we need 4 red, while we only have 3.	It has been revised by simplifying sentences more
It feels less 'natural' if out of nowhere the teacher asks where do you want to study? I feel the settings are not natural. Wouldn't it be better if the context was added first, for example in order, for there to be permission to study outside, with choices? I think the story could flow more smoothly	The language in the place setting editor is less natural	Context has been added to place settings to make it more natural.

3.1.2. Practicality

One-to-One Evaluation

This evaluation were carried out at 5 special schools in West Sumatra, namely: City of Bukittinggi, Paya Kumbuh, Padang, Solok, and Batusangkar. There were 4 deaf students at Bukit Tinggi SLB, 4 intellectual disability students in Payakumbuh, 5 intellectual disability students in Padang, 2 deaf students and 2 intellectual disability students in Solok, and 5 intellectual disability students in Batu Sangkar. The Practicality Test was also carried out for one teacher in each school, so there were 5 teachers who observed the learning process being carried out and filled out product practicality questionnaires. In the following, the results of the practicality of students and teachers are presented as well as the input and thinking processes of students when learning using e-comic.

After carrying out the learning process students are given a practical questionnaire with the results presented in Table 3.

Table 3. Mathematics e-comic's practicality based on the students

Aspects	Practicality Average	Criteria
Attractiveness	91.66	Very Practice
User Ease	91.66	Very Practice
Benefit	86.6	Practice
Average	89.98	Very Practice

Based on Table 3, it is obtained that the attractiveness and convenience of e-comics is in the very practical category, while the benefits felt by students are in the practical category. When given exercises about addition, subtraction questions, and questions related

to solving problems in everyday life to students, the responses obtained by students were that some students were able to complete and some were unable to complete the results of which can be seen in Table 4.

Table 4. Students' result on addition, subtraction questions, and questions related to solving problems in everyday life

City	Student (Disability)	Addition	Subtraction	Solving Problems in Everyday Life about addition and/or Subtraction
Bukittinggi (SLB Negeri 1 Bukittinggi)	MEF(D)	Capable	Capable	Not Capable
	MKA(D)	Capable	Not Capable	Not Capable
	SPK(D)	Capable	Capable	Not Capable
	KZA(D)	Capable	Capable	Not Capable
Payakumbuh (SLB Luak Nan Bungsu)	AU(ID)	Capable	Capable	Capable
	AA(ID)	Capable	Capable	Capable
	SB(ID)	Capable	Not Capable	Capable
	AS(ID)	Capable	Capable	Capable
	DJ(ID)	Capable	Not Capable	Capable
Padang (SLB Negeri 1 Padang)	SH(ID)	Capable	Capable	Capable
	PT(ID)	Capable	Capable	Capable
	DP(ID)	Capable	Capable	Capable
	D(ID)	Capable	Capable	Capable
Solok (SLBS Lentera Bunda)	B(D)	Capable	Not Capable	Not Capable
	LL(D)	Capable	Not Capable	Not Capable
	SY(ID)	Capable	Capable	Capable
	L(ID)	Capable	Capable	Capable
Batusangkar (SLB Negeri 1 Pagaruyung)	SF(ID)	Capable	Capable	Capable
	MD(ID)	Capable	Capable	Capable
	RR(ID)	Capable	Capable	Capable
	AD(ID)	Capable	Capable	Capable

(D=Deaf, ID= Intelectual Disability)

Based on Table 4, all of the students are able to answer the addition questions, which means that all of the students are good at addition and for other topics, there are some of them cannot answer the questions.

Next, the e-comic practicality based on the teachers can be seen in Table 5.

Table 5. Mathematics e-comic's practicality based on the teachers

Aspects	Practicality Average	Criteria
Attractiveness	88.88	Practice
User Ease	81.94	Practice
Benefit	81.25	Practice
Average	84.02	Practice

Based on Table 5, the e-comic is practice for all of the aspects. This is means that the prototype can continue to the small group evaluation. Furthermore, the practicality of this product can also be seen on the students' activity while the learning process using e-comic. In Figure 9, it is presented that students already understand addition operations in learning to use e-comics using proton and electron media.

Figure 9. Students can solve addition problems

In Figure 9 it can be seen that students with special needs have been able to complete the "3 + 4" questions.

In the one-to-one evaluation there are also several things that must be revised, that are:

1) First define the concept of zero in e-comics, which is a pair of red (+1) and blue (-1)
2) Overcoming e-comics for the concept of subtraction which should take precedence over easier questions. Examples of questions in e-comics start from "4 – 3", while in e-comics it starts with questions "3 – 4", so students have difficulty picking up 4 red pieces
3) Students find it difficult to distinguish the negative sign in numbers from the minus operation sign

These deficiencies have been corrected in e-comics, namely as follows: add a scenario in e-comic that explains zero as shown in Figure 10.

Figure 10. Adding an explanation of zero

Figure 10 has added the introduction of colored chip media (Proton - Electron), namely 1 proton chip (red color chip) and 1 electron chip (blue chip) worth 0 (zero) which was introduced before starting to give questions. Furthermore, based on the learning process carried out, it should be added to the easier subtraction questions first, such as 4 – 3, before problems 3 – 4. These improvements are presented in Figure 11.

Figure 11. A simpler problem in subtraction

Furthermore, the solution to the problem in Figure 10 is also added to the e-comic which can be seen in Figure 12.

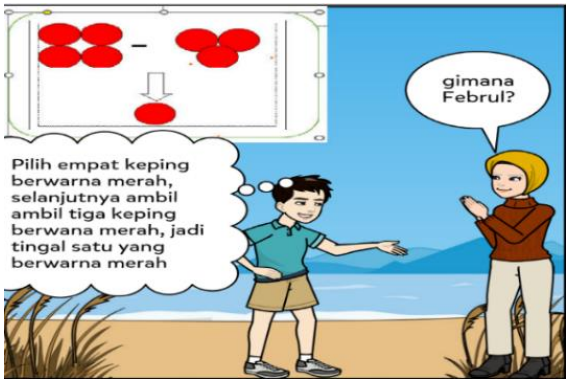
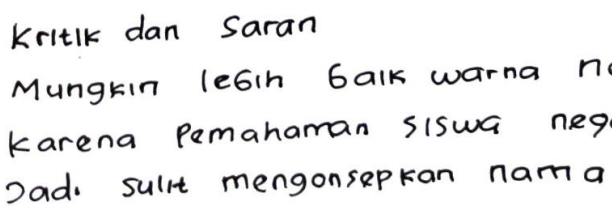


Figure 12. Solving problems in reduction

When solving questions on the concept of subtraction, it was found that students had difficulties in differentiating fewer operations from negative numbers. For example, in questions 3 – 4, students find it difficult to interpret the minus sign (-) in number – 4. Students are confused about whether to add blue chips or take 4 red chips each. To distinguish this, emphasis is given to giving questions with variations on the sign of the operation in the e-comic exercise presented in Figure 13.

Figure 13. Various problems to emphasize sign differences

Based on the questionnaire, the SLB Negeri 1 Bukittinggi teacher gave advice to replace the red color as a chip for negative numbers and blue as a positive number, because according to the teacher, the students had already conceptualized red as a negative number. SLB Negeri 1 Bukittinggi teacher's criticism and suggestions are presented in Figure 14.

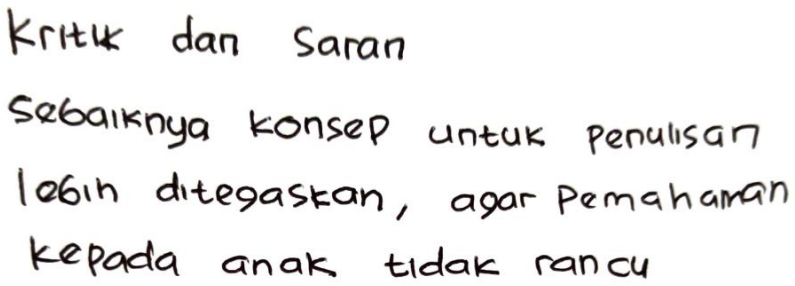


Translation:
Maybe it's better to replace negative and positive colors because students understand that negative is red, so it's difficult to conceptualize the difference between colors

Figure 14. Mathematics e-comic's practice

For this section, the color revision of the colored chips is not carried out in e-comics because the colors used usually in many sources are red chips to represent positive numbers and blue chips to represent negative numbers, but the teacher can change colors when using the media if needed so that students can better understand the concept.

Furthermore, the SLB Luak Nan Bungsu teacher gave criticism and suggestions, namely to be careful in writing signs so that students are easier and not mistaken in understanding the concept. Screenshots of SLB Luak Nan Bungsu teachers can be seen in Figure 15.

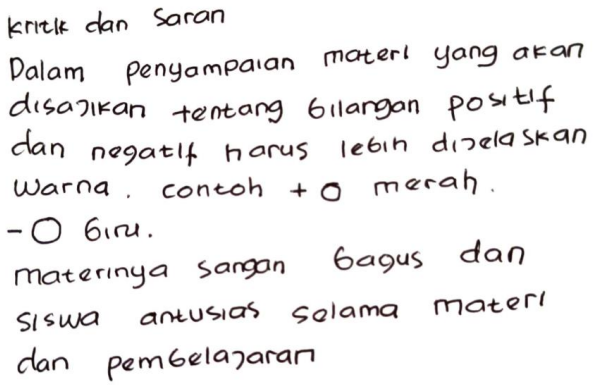


Translation:
It is better if the concept of writing is more enforced so that children's understanding is not confusing

Figure 15. Mathematics e-comic's practice

For input from SLB Luak Nan Bungsu teachers, some of the writing of operational signs on questions in e-comics has been revised.

Furthermore, the SLB Negeri 1 Padang teacher gave input that they had to provide input to first define the number zero with red and blue pieces and the material was very good and enthusiastic in following the subject matter. Screenshots of SLB Negeri 1 Padang teachers can be seen in Figure 16.



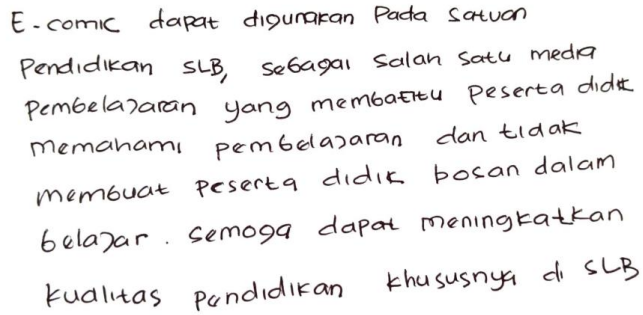
Translation:
In delivering the material to be presented about positive and negative numbers one by one the symbols and colors of the example +o red -o blue material is very good and students are enthusiastic while following the material and learning

Figure 16. Mathematics e-comic's practice

The revision of suggestions from SLB Negeri 1 Padang teacher has been carried out, because students also have difficulty defining the number zero for the introductory part of the introduction of colored pieces.

SLBS Lentera Bunda teachers did not provide criticism and suggestions in the questionnaire but during the implementation of the learning process the teacher said the e-comic learning process with the help of learning tools was very interesting and motivated students to learn.

Furthermore, the SLB Negeri 1 Pagaruyung teacher made a recommendation that e-comics could increase the interest and motivation of SLB students in learning addition and subtraction material, as can be seen from the snippet of the teacher's suggestion in Figure 17.



Translation:
E-comics can be used in SLB education units, as one of the learning media that helps students understand learning and does not make students bored in learning. Hopefully, it can improve the quality of education, especially in SLB.

Figure 17. Mathematics e-comic's practice

The teacher's input and suggestions were very helpful in developing e-comics for students with special needs in understanding the concept of addition and subtraction in integer material.

3.2. Discussion

In theory, the skills and professionalism of teachers greatly affect the skills and achievement of students in learning (Harisman, Kusumah, Kusnandi, et al., 2019; Harisman et al., 2020; Harisman, Noto, & Hidayat, 2021; Hidayat & Aripin, 2019; Irwandi et al., 2019). For this reason, teachers must always have innovation in developing the learning process in all lines of education, including students with special needs. Teachers must believe that students with special needs have the same desire in the learning process as other students (Gonçalves & Lemos, 2014). Teachers in schools with special needs must also have confidence that students with special needs have the talent and ability to accept technology, learning media, and so on, just like students in regular schools (Fernández-López et al., 2013). Teachers' high confidence in students will influence the teacher's way of developing innovative learning media that can help students develop the potential that exists in them (Harisman, Kusumah, & Kusnandi, 2019; Hidayat & Husnussalam, 2019).

Students with special needs have many limitations such as limited intelligence, hearing, vision and so on. Therefore, it is necessary to develop learning media for students with special needs to increase their learning motivation even in a deprived state (Fernández-López et al., 2013). The teacher is the main factor in supporting this to materialize (Hendriana et al., 2022), because after conducting research it is found that special school students are also interested in the e-comics being developed. Interesting teaching materials can also make the mathematical abilities of students with special needs develop such as the ability to think critically, logically, and understand concepts (Brame, 2000). For this reason, teachers should continue to innovate to develop learning that is fun for the learning process of special school students.

Based on the results of the research, mentally retarded students can solve the problems given well with the media. Meanwhile, for deaf students there are still some problems that are constrained and cannot be resolved. This means that this learning media can be considered appropriate for students with this type of intellectual disability. Meanwhile, for deaf students it is necessary to look for other, more appropriate solutions to assist in facilitating students in the learning process. This is in line with expert opinion that mentally retarded students will tend to be more interested in visual media and lots of colors (Fernández-López et al., 2013; Sabaruddin et al., 2020; Shamir & Lifshitz, 2013). For this reason, a conclusion can be drawn that teachers must pay attention to the tendencies of each disabled special needs student and develop suitable media. Because the media developed by the teacher is also closely related to the learning achievement of students, including students with special needs (Muir & Beswick, 2007).

4. CONCLUSION

The conclusion obtained from the research results is that the mathematical e-comics developed for students with special needs are valid and practical. Of the five schools that were used as research sites where each school was represented by 4-5 students with special needs with different types of disabilities, almost all of them were able to complete the concept of addition, subtraction, and word problems related to the concept. Only a few students with this type of disability who are deaf have problems solving subtraction problems. As for practicality for teachers who make observations in each class, they also say

that the media used is interesting and practical for students with special needs in understanding learning material. The things that became findings in the study included: students found it difficult to distinguish between less and negative operations, deaf students have difficulty understanding sentences in comic stories, the definition of the number zero must also be emphasized on the colored chips in e-comics. The implication of this research is that teachers should develop other IT-based teaching media according to the types of disabilities of students with special needs because it can help students be more motivated in learning.

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