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The Development of Learning Tools for Students with Comorbid Dyscalculia-Dyslexia

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THE DEVELOPMENT OF LEARNING TOOLS FOR STUDENTS WITH COMORBID DYSCALCULIA-DYSLEXIA

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Abstract

This study aimed to develop learning tools to help children with learning disabilities of comorbid dyscalculia-dyslexia. The learning tools were developed using the 4D model. Each stage of development was conducted based on the materials focused on in this research, namely the topics of recognizing and understanding numbers, sorting numbers, and operating numbers. This study involved 280 students, ages between 7 and 8 years old, from four elementary schools. Students took a series of tests, and 11 students were found with comorbid dyscalculia-dyslexia. The results of this study provided an overview related to the learning tools developed, tested, and implemented in mathematics learning for students with dyscalculia and dyslexia. This finding was indicated by the analysis results of recognizing numbers, sorting numbers, and operating numbers using paired-sample t-tests ($p < 0.05$). The results showed increased students' essential mathematics ability based on the pretest and posttest scores.

Keywords: Learning Media; Learning Difficulties; Dyscalculia; Dyslexia.



A. Introduction

Children with learning disabilities tend to experience significant difficulties in learning, such as difficulties in reading, writing, and mathematics (Avila-Pesantez et al., 2019; Barbaresi et al., 2005; Mazzocco et al., 2011; Miundy et al., 2017). Learning disabilities are indicated by a significant difference between general intellectual abilities and academic achievement (Prior et al., 2016). Our research focuses on developing learning tools for children with learning disabilities in mathematics (dyscalculia) who also have reading problems (dyslexia). Interventions to help overcome early difficulties are appropriately needed by children with dyscalculia in learning (Griffin, 2004; Monuteaux et al., 2005). The interventions to overcome initial difficulties can help reduce the subsequent effects that will be carried over into adulthood.

Despite the positive effects of learning interventions for children with learning disorders, there are weaknesses in overcoming the difficulties for children with dyscalculia by ignoring their comorbidities, so learning interventions for students with learning difficulties are often applied singly. Many children with dyscalculia may also have dyslexia simultaneously (Boets & Smedt, 2007; Geary & Hoard, 2001; Landerl & Moll, 2010). Several studies have revealed that comorbidities among children with dyscalculia and dyslexia are very high (Moll et al., 2014; Moreau et al., 2018; Willcutt et al., 2013), where children with learning disorders often experience co-occurring dyscalculia and dyslexia.

In addition, lately, learning disorders in mathematics and reading have been mainly studied separately, focusing on a single learning disorder while ignoring simultaneous features (Moll et al., 2020; Vanbinst et al., 2020). Hence, different conclusions are found when directly investigating children experiencing both dyscalculia and dyslexia (Fuchs et al., 2013; Geary & Hoard, 2001). Recent research also confirms that students with the mathematical disorder are more than twice as likely to have a reading disorder (Joyner & Wagner, 2020), and there is an increase in the number of students identified as having comorbid Dyscalculia-



Dyslexia (Witzel & Mize, 2018). Unfortunately, comorbid disorders experienced by students have not been integrated into the educational intervention plan (Hendren et al., 2018). Moreover, there is still little research on learning interventions for children with comorbid Dyscalculia-Dyslexia. Generally, biological perspectives dominate more recently published research concerning these issues than educational perspectives (Lopes, 2012).

Teachers must have exceptional abilities in handling the problem of comorbid Dyscalculia-Dyslexia in school. However, many teachers in schools do not have a good understanding and sufficient knowledge to help students to overcome the problems related to learning disorders (Miundy et al., 2017; Wadlington & Wadlington, 2005), including in children with comorbid Dyscalculia-Dyslexia. Supposedly, educators and parents need to know the causes of students' learning disorders (Perkin & Croft, 2007). Practical and positive strategies are needed for teachers to help students to overcome the problems of students with learning disorders: children with dyscalculia, dyslexia, and the comorbidity of both (Perkin & Croft, 2007; Sutton & Shields, 2016; Witzel & Mize, 2018). Unfortunately, there has been little concern about this condition (Fuchs et al., 2013).

It becomes difficult for students who experience dyslexia to understand and solve their mathematical problems at school. If initial difficulties are not dealt with effectively, the difficulties encountered in class will be added to the inherent difficulties resulting in prolonged learning failure (Chinn & Ashcroft, 2006). If a child cannot follow the curriculum well or exhibits behavioral problems, they may face learning difficulties (Abo El-Gamelan Ebrahim Essa & Mohamed Ahmed El-Zeftawy, 2015).

In Indonesia, many children with dyscalculia and dyslexia in primary school are without special attention or teacher assistance. So, students are constrained in their learning. Meanwhile, children in primary classes need to master the core components of the school curriculum, such as reading and mathematics skills (Fuchs et al., 2013). Unfortunately, many teachers do not understand the learning disorders experienced by their students, or they



have somewhat limited knowledge (Wadlington & Wadlington, 2005). Teachers use the same learning tools for all students, including children with comorbid Dyscalculia-Dyslexia (Azhari, Yacoub, & Irfan, 2020).

Several studies that have been conducted on web-based learning and mobile technology-based applications have also been developed to help students with dyscalculia (Miundy et al., 2017; Muñoz-Arteaga, 2020). However, many teachers complain about the lack of access, availability, and technical support to help students with dyscalculia and dyslexia (Miundy et al., 2017). So, special learning tools must be designed for students with comorbid Dyscalculia-Dyslexia. It will also be alternative learning for teachers in schools that do not have access to use web-based learning and technology-based applications. So far, there has been little research explicitly developing mathematical learning tools for students with comorbid Dyscalculia-Dyslexia, especially in public schools that do not have special programs and understanding of the learning disorders.

B. Method

This development research applies the 4-D model: define, design, develop, and disseminate (Thiagarajan, 1974). This study presented up to the development stage, which is the making of student worksheets, manipulatives, and manuals for teachers to teach dyscalculia children who are also with dyslexia.

1. Research Procedure

This research follows the 4-D model of development research, including:

Define: At this stage, a preliminary analysis consists of defining the literature needed in learning for students with comorbid Dyscalculia-Dyslexia by analyzing the objectives and limits of the subject matter according to the grade of students with comorbid Dyscalculia-Dyslexia. This stage consists of five steps: (a) initial analysis, (b) student and



environmental analysis, (c) material analysis, (d) task analysis, and (e) specification of learning objectives.

Design: This stage is carried out to design learning tools and research instruments resulting in a prototype (the sample of learning tools and research instruments). Activities carried out at this stage consist of four activities: (a) preparation of test instruments, (b) media selection, (c) format selection, and (d) initial design.

Develop: This phase aims to produce a final draft of learning tools and research instruments that will be developed repeatedly, starting from Draft I, II, to III (final draft). This stage consists of three activities: (a) expert assessment, (b) readability test and learning plan simulation, and (c) testing of learning tools and research instruments.

Disseminate: This stage is conducted after the design and development stages. In this stage, the research results are published as scientific articles in journals.

2. Participants

This research involved 280 (150 female and 130 male) elementary school (SD) students aged between 7 to 8 years from four different schools. One hundred forty-two students were seven years old, and 138 were eight. Mathematics Learning Ability (MLA) and Mathematics learning performance (MLP) were administered to 280 students. Based on the analysis and the data validity assessment done repeatedly, 25 students with dyscalculia were found through Dyscalculia Assessment (Emerson & Babbie, 2014), including the tests to recognize numbers, sort numbers, and operating numbers. Furthermore, out of 25 students with dyscalculia, 20 students had dyslexia. This test considered four variables with steps in reading skills: phonological awareness, rapid naming, spelling, and range of numbers (Jap et al., 2017). Based on the simple word reading skills test, 11 students were found with comorbid Dyscalculia-Dyslexia.



3. Research Instrument

The validation of learning tools and research instruments includes content validity, conformity with students' thinking levels, and conformity with main principles, characteristics, and learning steps. Validation was carried out with a pilot study in a small sample size to check its feasibility, reliability, and validity. The instrument developed follows the essential mathematical competencies that students must master, including the problem of sorting numbers, addition operations, and subtraction operations. Furthermore, the data collected in this study is about the quality of learning devices. The instrument used is a validation sheet which includes the appropriateness of content, language, format, and graphic illustrations (Akpinar, 2008; Singh & Bernard, 2016).

4. Data Analysis

In line with the primary objective of this research, which is to produce excellent or valid learning tools for teaching mathematics to students with comorbid Dyscalculia-Dyslexia, the data analysis in this study is to refine or revise learning tools from drafts I to II, and then Draft III (final draft). The assessment of learning tools given by the validator was then compiled and analyzed quantitatively based on a Likert scale (interval 1-5), with 1 - strongly disagree, 2 - disagree, 3 - neutral, 4 - agree, and 5 - strongly disagree. The average score given by the validator is then generated and interpreted based on the criteria presented in table 1. In addition, the analysis uses a t-test on students with comorbid Dyscalculia-Dyslexia, to measure essential mathematical competencies, including problems sorting numbers, addition operations, and subtraction operations.

Table 1: Interval criteria for learning tools assessment

Score Range	Criteria
$\bar{x} > 4,2$	Excellent
$3,4 < \bar{x} \leq 4,2$	Good
$2,6 < \bar{x} \leq 3,4$	Average
$1,8 < \bar{x} \leq 2,6$	Poor
$\bar{x} \leq 1,8$	Very poor

(Sugiyono, 2015)



C. Result and Discussion

1. Result

The development of learning tools for students with comorbid Dyscalculia-Dyslexia follows the 4-D development model: define, design, develop, and disseminate.

a. Define Stage

The define stage aims to establish everything needed in learning for students with comorbid Dyscalculia-Dyslexia. Analyzing the characteristics of students with comorbid Dyscalculia-Dyslexia was conducted through a literature review and field observations. In a literature review, researchers found several problems in children with comorbid Dyscalculia-Dyslexia. Children with dyscalculia experience learning difficulties, including difficulties sorting numbers, understanding numbers and values, understanding symbol operations, and performing number operations (addition, subtraction, multiplication, and division).

The observation and test results showed that some children with dyscalculia were also experiencing dyslexia. Table 2 presents the test results.

Table 2: Number and proportion of children with dyscalculia, dyslexia, and comorbid dyscalculia-dyslexia by age and gender

Age	Gender, N	Dyscalculia Assessment, N (%)	Dyslexia Assessment, N (%)	Comorbid Dyscalculia-Dyslexia, N (%)
8-9 years	Male, N = 150	14 (5.0)	11 (3.9)	7 (2.5)
	Female, N = 130	11 (3.9)	19 (3.2)	4 (1.4)
	Total: N = 280	25 (8.9)	20 (7.1)	11 (3.9)

Table 2 shows that the analysis of student data and observation revealed that students in grade I first elementary school (age 8) should have been able to master first-grade mathematics materials, including; sorting numbers, understanding numbers and their values, and understanding symbols operations. At the same time, class II I (age 9)



should have been able to carry out simple number operations (addition, subtraction, multiplication, and division) because they learned in class II, by the 2013 curriculum in force in Indonesia. It was found that students who had problems with material that should be mastered, according to their age and school level.

However, the selected teaching material in this study was not specific to a particular topic in mathematics; it emphasized more on fundamental matters, which are also the background for the child to be identified with dyscalculia. Therefore, based on the results of material and task analysis, the learning objectives were specifically structured so that: (1) students are able to understand numbers and values, (2) students are able to subtract numbers from the smallest to the largest numbers and vice versa, and (3) students able to understand the symbols of operations and carry out number operations (addition, subtraction, multiplication, and division).

b. Design Stage

This phase aims to design learning tools and research instruments so that a prototype is created (the sample of learning tools and research instruments). This stage consists of four activities: (a) preparation of test instruments, (b) media selection, (c) format selection, and (d) initial design.

In the preparation of test instruments, we designed the mathematics skills test based on the result of material analysis, task analysis, and specification of the objectives of learning mathematics. Tests developed in the research were limited to the test of students' learning ability to examine the disorder or problems faced by students with comorbid Dyscalculia-Dyslexia and to measure the achievement of learning objectives that students should achieve. The resulting product was used as feedback on the implementation of future learning. This test was planned in the form of a short-answer question.

The media selection was carried out to determine the appropriate media and learning tools to be used in the implementation of learning for students with comorbid Dyscalculia-Dyslexia. This media selection process was adapted to the results of task analysis, concept analysis, and analysis of students and the environment so that it was relevant to be used in the learning process in helping the learning difficulties of students with comorbid Dyscalculia-Dyslexia. Next, format selection included the selection of formats for designing the contents, strategies, approaches, learning methods, and learning resources that to be developed for students with comorbid Dyscalculia-Dyslexia.

Lastly, the initial design involved compiling or writing a draft of the learning tools, including the first draft of (1) Lesson Plan, (2) Student Books, (3) Student Worksheets, (4) Teacher's Manual, and (5) Test of Student Learning Outcome. Simultaneously, a research instrument was prepared, which would be used as a research data collection tool. The first draft of research instruments was also designed, namely: (1) Validator Assessment Sheet for the learning tools and research instruments, (2) Observation Sheet for teachers' ability to manage the learning, (3) Observation Sheet for student activities, and (5) Tests of Student Learning Outcome.

c. Development Stage

At the development stage of the learning tools, the learning tools developed included the student worksheet according to the initial design. It was then validated by some experts in the areas of language and mathematics. The experts referred to in this case were the validators who are competent to conduct an assessment of the learning tools and research instruments by taking into account the problems of learning disorders for students with comorbid Dyscalculia-Dyslexia. After the revision and analysis of the validation results, the student worksheet indicated a valid score for each aspect. Furthermore, the student worksheet was tested in a



small group to examine the readability and, in a large group, testing to assess the practicality. The results of the student worksheet validation can be seen in table 3.

Table 3: Learning tools validation results

No	Rated aspect	Validator			The mean	Percentage	Category
		1	2	3			
1	Format	3.5	4.0	4.5	4.00	80%	Good
2	Content	4.5	4.5	4.5	4.50	90%	Excellent
3	Language	3.5	3.5	4.0	3.67	73.3%	Good
4	Illustration of Images	4.0	4.5	4.5	4.33	86.6%	Excellent

Learning tools for children with the learning disorders of comorbid Dyscalculia-Dyslexia that have been developed and tested subsequently applied to one of the schools selected. The implementation process was carried out by completing student worksheet I, II and III in each meeting. The observation was also conducted to describe the activities the students undertake. While working on student worksheet I, II and III, students were accompanied by two teachers. The observation results of student worksheets I, II, and III can be seen in table 4.

Table 4: The observation results of learning implementation

Meeting	Observer		The mean	Percentage	Category
	1	2			
I	3.1	2,9	3	60%	Adequate
II	3.5	3,4	3.45	69%	Good
III	4	3,9	3.95	79%	Good

Table 4 shows the observations on the implementation of mathematics learning at each meeting using student worksheets I, II and III. At the first meeting, a percentage of 60% was obtained (adequate category). Furthermore, at the second and third meetings, a percentage of 69% and 79% was obtained, respectively (good category). The observations results indicate a positive change from the first meeting to the subsequent meeting.



Figure 1 displays an example of part of the drawing from the student worksheet containing the basic mathematics competencies from draft I to II, which was revised based on the observations of students in the first meeting.

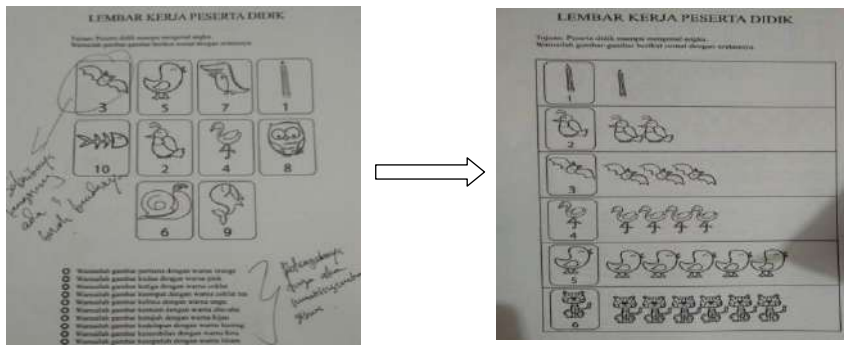


Figure 1: Identifying numbers in student worksheet I

The changes in Figure 1 were in line with the validator's recommendations; student worksheet I was made in tabular and sequential form to make it easier for children with comorbid dyscalculia/ dyslexic to understand numbers. Before the revision, in the first draft, some instructions confused the students. So, it was adapted to cater to children with dyslexia and avoid wordiness.

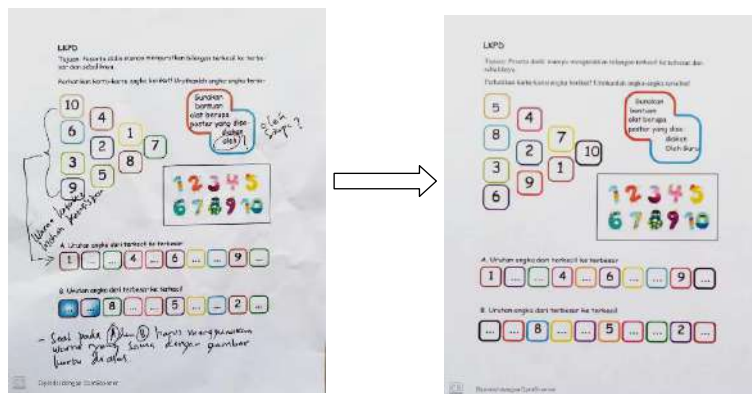


Figure 2. Sorting numbers in student worksheet II

The changes in figure 2 occurred based on the suggestion from one of the validators, who suggested that the numbers and colors of the numbers

must be adjusted with the instructions given to the students (first draft). Students with learning disorders tend to be more visual and see color matching based on the examples provided (draft II). Then it is suggested that the order of the color boxes in the instructions should be adjusted to the example of the color boxes given in numbers.

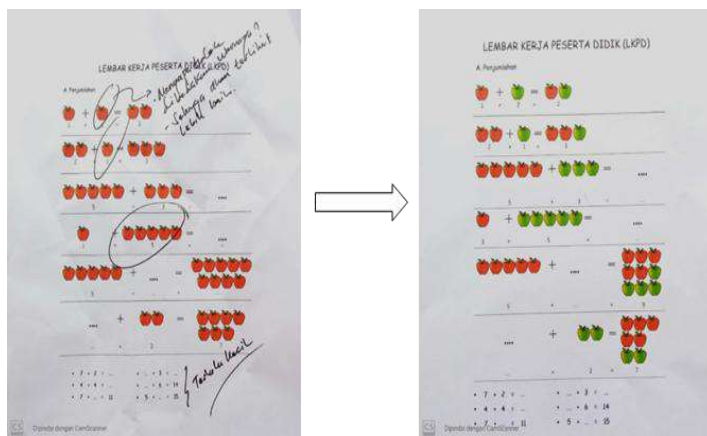


Figure 3. Sum of numbers in student worksheet III

Figure 3 shows the changes in the draft II to III of student worksheet related to color changes. This is in accordance with the suggestions and the validator's notes, which also had previously undergone a change from draft I. It focused on one color only in draft II, but it was modified to multicolor in draft III. The validator argued that children with learning disorders prefer various colors to increase interest in learning.

Table 5: The results of student activities in mathematics learning

No	Assessment Aspects	Percent of Student Activity (%)			Average
		I	II	III	
1	Recognizing and Understanding the number values	2.9	3.3	3.5	3.23
2	Sorting Numbers	3.2	3.7	4.1	3.67
3	Operating Numbers	3.7	4.2	4.5	4.13

The criteria of student activities in table 5 shows that, in every aspect of each meeting, students were dominantly carrying out activities



relevant to learning. Students completed the assignments given to them and often listen to instructions from the teacher in the process of solving them. Furthermore, after students conducted the learning process for three meetings using the draft of the student worksheet that was revised in each meeting, the test of learning outcomes was conducted. It focused on the topic of recognizing and understanding number values, sorting numbers, and operating numbers. The data from the test of these three aspects presented in Table 5 were analyzed using paired sample t-tests using SPSS 22. The results of the paired sample t-test for each aspect are presented in tables 6, 7, 8.

Table 6. Summary of statistical test of recognizing and understanding number values

Paired Samples Statistics				Paired Test Samples		
Pairs	The mean	N	Std. Dev	Pairs	Df	Sig.
Pretest	49.50	12	4.05	Pretest-posttest	11	0.000
Posttest	35.67	12	2.10			

The results of the normality and homogeneity tests were both not significant ($p=0.195$ and $p=0.417$, respectively). Thus, the data were normally distributed and homogeneous. The results of the paired sample t-test of the ability to recognize and understand number values indicated the significant mean difference between the pretest and posttest scores ($p=0.000$) (table 6). It means that there is an increase in the ability to students' ability to recognize and understand number values between the pretest and posttest.

Table 7: Summary of statistical test of sorting numbers

Paired Samples Statistics				Paired Test Samples		
Pairs	The mean	N	Std. Dev	Pairs	Df	Sig.
Pretest	46.25	12	2.37	Pretest-posttest	11	0.000
Posttest	33.42	12	1.56			

The results of the normality and homogeneity tests of sorting numbers were both not significant ($p=0.200$ and $p=0.590$, respectively); thus, the data were normally distributed and homogeneous. The paired sample t-test of the ability to sort numbers showed a significant result,



indicating the significant mean difference between the pretest and posttest scores ($p=0.000$) (table 7). It means that there is an increase in students' ability to sort numbers between the pretest and posttest.

Table 8: Summary of statistical test of operating numbers

Paired Samples Statistics				Paired Test Samples		
Pairs	The mean	N	Std. Dev	Pairs	Df	Sig.
Pretest	46.33	12	2.42	Pretest- posttest	11	0.000
Posttest	31.00	12	1.75			

The results of the normality and homogeneity tests of operating numbers were both not significant ($p=0.161$ and $p=0.355$, respectively), thus the data were normally distributed and homogeneous. The paired sample t-test of the ability to operate numbers showed a significant result, meaning that the pretest and posttest scores ($p=0.000$) were significantly different (table 8). It means that there is an increase in students' ability to operate numbers between the pretest and posttest.

2. Discussion

Children with comorbid Dyscalculia-Dyslexia must have special treatment using special learning tools. The teaching materials used should also be different. So this research tries to develop learning tools to help children with comorbid Dyscalculia-Dyslexia. It aims to help children with learning disorders to not be left behind by other children in learning mathematics in school. Also, teachers are responsible for helping children with learning disorders by taking a learning approach that supports children to overcome the problems related to the learning disorders (Abo El-Gamelan Ebrahim Essa et al., 2015). The existence of these special learning tools is expected to assist teachers in helping students learn in the classroom and, at other times, tailored to student circumstances.

The development of this learning tool was conducted in several stages, and several drafts of the learning tools were obtained, which were then validated by experts. The validation process and advice from experts



improve the products being developed using learning activities (Gunawan et al., 2020). In this study, the first draft of the learning tools was developed based on a theoretical study conducted at the define stage. It mainly focused on understanding the possible reasons for the simultaneous reading and mathematics inabilities, including the same dependence on phonological processing, memory, or executive functions; similarities between numbers and letters for the alphabet writing system; and the fact that a lot of mathematics requires reading, as well as difficulty seeing pattern connectedness of numbers and also patterns of numbers (Emerson & Babbie, 2014; Joyner & Wagner, 2020).

The first draft was designed to fit the theories about the obstacles experienced by children with dyscalculia. Furthermore, draft II was obtained from the development of draft I through discussion and input from several experts. Whereas draft III was produced after the field trials. The obstacles faced by students and teachers in the learning process were taken into consideration for the improvement of the learning tools as a final draft.

The drafts of learning tools developed include student worksheets, which were developed to help dyscalculia children with comorbid Dyscalculia-Dyslexia learn mathematics with various mathematical activities suiting the children's learning disorders. This student worksheet was developed by minimizing reading because this study focused on Children with comorbid Dyscalculia-Dyslexia. So, the learning tools developed need to consider problems commonly experienced by children with dyslexia, for example, deficits in visual perception as the impact of cognitive mechanisms (Cheng et al., 2018; Miundy et al., 2017). Children with dyslexia are disturbed when they read words, but not when they give the appropriate picture names (Joyner & Wagner, 2020). Therefore, learning tools developed are more dominant with pictures and other visual media representing numbers or things that are considered difficult by students with dyscalculia.



Visualization is useful in building understanding and strengthening student memory. On the other hand, because working memory is impaired in individuals with dyscalculia, they may choose to use calculations more often because this is less demanding of working memory (Weijden et al., 2018). So the learning tools are designed to intervene students with comorbid Dyscalculia-Dyslexia with various mathematical activities and consider student activities in understanding abstract concepts through their learning activities. Moreover, they need to understand abstract mathematical principles (Kay & Yeo, 2003) through concrete and real learning activities.

Mainly, to be able to explain numbers, students must understand how numbers consist of patterns and structures. Students need to become familiar with various number patterns and a base of ten and a place value structure. This activity requires additional time for students with comorbid Dyscalculia-Dyslexia. It is as described by Brennan & Harrison (2020) that extra time for students is a reasonable adjustment for several learning difficulties in students.

Learning tools developed are also equipped with teacher manual, considering the characteristics of conditions commonly experienced in mathematics learning activities, because dyscalculia students often have problems in retrieving and using numerical facts quickly (such as on the multiplication table) and also procedural activities (such as in division). Even if they produce the right answer or use the right method, they can do it mechanically and without confidence and have no way of knowing or checking that the answer is correct (Chinn & Ashcroft, 2006). Hence, these characteristics are a basic consideration in developing learning tools.

Furthermore, the description of student learning outcomes shows progress in every problem experienced by students with dyscalculia in understanding mathematics because students are taught through pictures that represent numbers, from recognizing and understanding numbers to sorting numbers to number operations. Although this study has shown



the progress in learning for students with comorbid Dyscalculia-Dyslexia, the learning tools can only anticipate students from being frustrated in learning mathematics due to too much reading they must understand for children with dyslexia. On the other hand, dyslexia is a complex problem that requires special attention to handle. Hence, in this case, the learning tools developed in this study cannot completely overcome the problem of dyslexia; it still focuses more on the problem of dyscalculia. This becomes the limitation of this study, which should be addressed in further research.

D. Conclusion

This research contributes to a learning device product developed for children with comorbid Dyscalculia-Dyslexia. The development of learning tools is carried out in four stages of the 4-D model, namely: to define, design, develop, and distribute. In this study, each stage was adjusted to the material that was the focus of this study, namely the basic material for identifying students with dyscalculia: recognizing and understanding number values, sorting numbers, and number operations. Based on the data analysis of the ability to recognize and understand number values, sort numbers, and operate numbers using paired sample t-test, significant results were obtained ($p=0.000$).

This shows the progress and improvement of students' learning abilities with comorbid Dyscalculia-Dyslexia for each material taught. The learning tools developed were also tested and implemented in mathematics learning for comorbid Dyscalculia-Dyslexia students. Positive results were obtained and obtained both in terms of student activity in learning using aids and learning outcomes tests. From the pretest and posttest scores, the learning outcomes of basic math skills in students with comorbid Dyscalculia-Dyslexia increased.



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