Development of augmented reality-based learning models for students with specific learning disabilities

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Abstract

This study aims to develop a learning model based on augmented reality applications to overcome barriers to learning mathematics for Students with Specific Learning Disabilities (SLD) in Inclusive Schools. This study uses a 4D model with the development of an AR-based learning model involving ten expert validators, and the respondents employed in the analysis of data collection needs at the specified stage are 40 Special Education Teachers (STC) who teach SLD students in inclusive schools. The results of this study indicate that research on the achievement of the learning process shows that there is still hope and excellence in achieving the learning process desired by STC, where the learning process is still in the sufficient category level and necessary, as a learning medium in the learning process in the inclusive class. The validation test also shows that augmented reality application technology is included in the very good category, including the very good class. This augmented reality-based learning model is valid for use in the learning process in overcoming barriers to learning mathematics for SLD students in inclusive schools.

Keywords: Augmented Reality, inclusive schools, mathematic, learning model, SLD

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1. Introduction

In this industrial era, 4.0 technology development is increasing. In the world of education, the development of science and technology in the learning process uses media and learning resources developed based on science and technology (Irwansyah et al., 2018). The law-mandated learning based on Permendikbud No. 22 of 2016 states that the learning process in the academic unit is organized interactively, inspiring, fun, challenging, motivating students to participate actively, so that students with specific learning disabilities in inclusive schools can learn in one inclusive class with regular learners.

Students with learning disabilities lead to low learning achievement in one or more subjects in school (Kalsoom et al., 2020). Learning disabilities is a disorder that is manifestly a child related to general and special tasks, which is thought to be caused by neurological dysfunction factors, psychological processes, and other causes so that students specific learning disabilities in a class show low learning achievement (Kauffman et al., 2011). This is because understanding takes a long time and repeat learners with specific learning disabilities understand new concepts such as counting in mathematics learning (Noga, 2016). In mathematics, learning is an abstract subject and requires a long repetition in understanding the material by specific students with learning disabilities or regular learners (Utari et al., 2019).

The difficulty factor of learning mathematics comes from within the child and outside the child, one of which is the factor of the school environment, especially the learning process in the classroom (Catalano, 2014). Learning factors that result in the difficulty of learning mathematics, namely teachers are not able to choose or use teaching methods that are following the subject and depth of the material; the absence of reward and motivation and teacher attention to students who are weak in mathematics; the teacher treats all learners equally regardless of the student's background and character; classroom atmosphere during teaching and learning activities tend to be rigid and severe so that students are less courageous to express their opinions; variations of the language used by teachers in conveying a concept less (Aro et al., 2019).

Preliminary studies conducted by researchers obtained results that students with specific learning disabilities in mathematics learning have a substandard score in schools that is ≤ 50. Materials that become a lot of difficulties in mathematics learning in specific students learning disabilities (SLD) among others; Counting operations, fractions, flat builds, and room buildings. This provides an overview of the need to design fun learning and make it easier to understand math materials to overcome the barriers of specific learning disabilities (SLD) students in math learning. Learning media becomes more exciting and more concise, although it does not detract from the essence of the material. One of the development of learning media that is still new is learning media using Augmented Reality (Quintero et al., 2019).

AR technology itself can be widely implemented in various learning media, such as smartphones and print media such as books, making it easier for users in terms of tools and facilities. It can produce exciting learning media at a low cost (Bower et al., 2014). The advantages of Augmented Reality are as follows (Mustaqim & Kurniawan, 2018) : 1) More interactive, 2) Effective in use, 3) Widely implemented in various media, 4) Simple object modelling, because it only displays a few objects, 5) Creation that does not cost too much, 6) Easy to operate. Augmented Reality (AR) is a technology that combines 2-dimensional or 3-dimensional virtual objects into a 3-dimensional natural environment and then projects these virtual objects in real-time (Aldalalah et al., 2019). AR in mathematics learning models for SLD students is beneficial in providing media that can display what is abstract into the concrete. Augmented reality offers an authentic experience in learning mathematics and a unique way of learning

with mobile media (Del Cerro Velázquez & Méndez, 2021; Joan, 2015). Conceptually, several studies have stated that Augmented Reality can improve problem-solving skills (Aldalalah et al., 2019). Augmented Reality media builds through children's in-depth understanding of the studied material (Sirakaya & Sirakaya, 2018). Other research confirms that Augmented Reality facilitates children's learning through the visualization process of objects that can be observed directly and concretely (Chang & Hwang, 2018). Abstract concepts for children, which are usually difficult to understand through oral explanations by the teacher, will become more concrete when explained using Augmented Reality media (Hiranyachattada & Kusirirat, 2020).

The use of AR in mathematics is very rarely used in previous studies by other researchers. Previous research that used AR was more about learning science to introduce nature and animals (Markamah et al., 2018). AR is applied to provide authentic experiences in Biology lessons in increasing students' learning motivation (Weng et al., 2019). The implementation of AR in mathematics learning was previously used to introduce spatial shapes for students (Chao & Chang, 2018). In addition, research that develops AR learning models in mathematics subjects is the introduction of spatial figures about geometrical nets and volume formulas (Andrea et al., 2019; İbili et al., 2020). In the research that will be carried out with a literature review, the development of learning models based on augmented reality applications overcomes the barriers to learning mathematics for SLD students with more material coverage, including; arithmetic operations, fractions, flat shapes, and wake up spaces.

With a learning model consisting of visuals and audio, it can provide concrete thinking stimulation that can allow SLD students to repeat and understand concepts more easily than the mathematics learning materials taught by the teacher (Karagozlu et al., 2019). Augment-ed Reality (AR) can help overcome children with learning difficulties with difficulty understanding abstract concepts. Augmented Reality (AR) helps concretize abstract objects/concepts into concrete. AR promises new teaching and learning models that better meet 21st-century learning needs (Elmqaddem, 2019). Therefore, this research will be very much needed by SLD in inclusive schools that experience obstacles in mathematics lessons to improve their learning outcomes. This study aims to develop learning models based on augmented reality applications to overcome the barriers to learning mathematics for students with Specific Learning Disabilities (SLD) in Inclusive Schools.

2. Methods

2.1 Research Design and Procedures

This research design uses development and survey methods. The development method used is 4D (four-D), consisting of defining, design, developing, and dissemination. The presentation of the data in this study focuses on defining, designing, and developing augmented reality-based learning models to overcome barriers to learning mathematics for students with SLD. The define stage aims to identify the primary problem so that it is necessary to develop an augmented reality-based learning model. The design stage consists of making prototypes, such as marker designs, AR user interface design flowcharts, and AR book designs. The development stage is developing an augmented reality-based learning model into a product ready for testing by experts. The validation test is to reveal the validity of the augmented reality that has been developed by using the survey method. This survey method will provide quantitative results from the validity of the augmented reality-based learning model. The augmented reality-based learning model involves ten expert validators who will assess the feasibility of the product that has been developed through a survey questionnaire. The results of expert validation will be used as material for revision of the augmented reality-based learning model that is being created before it is ready to be tested in the field.

2.2 Sample

Ten experts will validate augmented reality-based learning models. Validation experts will assess augmented reality-based learning models that have been developed through the survey questionnaires provided. The experts are selected based on their expertise in the scientific field following the products developed today. In this study, researchers appointed experts from Extraordinary Education, Educational Technology, Informatics Engineering, Learning Media, and Language. Respondents used in filling out the needs analysis questionnaire at the define stage were special accompanying teachers who taught SLD students in grades 4, 5, and 6 inclusion schools in Indonesia.

2.3 Instruments

The instruments used in this study are two instruments. The first is a needs analysis instrument used to identify initial problems so that the development of an augmented reality-based learning model is needed. There are 40 questions about Special Counselling Teacher (SCT) subjective questions about AR-based learning in the needs analysis instrument. The second instrument is the validity of the instrument. There are 30 statement items related to the augmented reality-based learning model. In this study, the instrument used was validated using an expert judgment strategy. The validity of this instrument consists of three categories to be assessed, namely didactic requirements, constructive requirements, and technical requirements. In this study, didactic requirements are requirements related to the process of finding concepts according to the applicable curriculum, showing individual differences so that good media can be used to measure students' abilities. Construction requirements are requirements related to sentence structure, simplicity of word use, and clarity suitable for students. Technical requirements are requirements related to language, writing, images, and displays in learning media. Kategori validasi ahli model pembelajaran matematika berbasis AR, sebagai berikut;

Table 1. Category of expert validation of AR-based mathematics learning model

No	Aspects	Quality Category	Value Interval
1	Learning Aspects	Excellent	$X > 15.66$
		Good	$8.40 < X \geq 15.66$
		less	$4.24 < X \geq 8.40$
		Not Good	$1.00 < X \geq 4.24$
2	Display Aspects	Excellent	$X > 15.66$
		Good	$8.40 < X \geq 15.66$
		less	$4.24 < X \geq 8.40$
		Not Good	$1.00 < X \geq 4.24$
3	Programming Aspects	Excellent	$X > 21.66$
		Good	$15.40 < X \geq 21.66$
		less	$8.24 < X \geq 15.40$
		Not Good	$4.00 < X \geq 8.24$
4	Curriculum Aspects	Excellent	$X > 15.66$
		Good	$8.40 < X \geq 15.66$
		less	$4.24 < X \geq 8.40$
		Not Good	$1.00 < X \geq 4.24$

3. Results

The results of this study focus on define, design, and developing augmented reality-based learning models to overcome the barriers of learning mathematics of students with SLD. Presentation of the results data obtained in the research that has been done in detail as follows;

3.1 Define stage

At the define stage, a needs analysis is carried out that aims to examine a phenomenon of product needs to be developed. The questionnaire used in this needs analysis collects information to determine the needs of mathematical learning models for students with SLD and augmented reality applications. Currently, there is still no accommodated model or learning media that can facilitate understanding the mathematics of SLD students. (Table 1)

Table 2. Analysis of The Needs of Augmented Reality-Based Mathematical Learning Models

No	Indicator	Percentage %
1	Availability of teaching materials	87.5
2	Availability of learning media	32.5
3	Desire to create a model	97.5
4	*Augmented Reality*	87.5
Total Range		76.25

Based on table 1 on the analysis of the needs of augmented reality-based mathematical learning models judging by indicators of availability of teaching materials, learning media, desire to create models, and augmented reality shows a percentage of 76.25%. These results fall into the category required by STC in AR-based mathematical learning models to overcome the barriers of learning mathematics of students with SLD.

3.2 Design stage

At this stage, the initial design of the prototype design of the AR-based mathematical learning model. This design phase includes the development of markers, flowcharts, user interfaces, and AR book drafts. The design of the AR system developed in this study can be seen in flowchart figure 1.
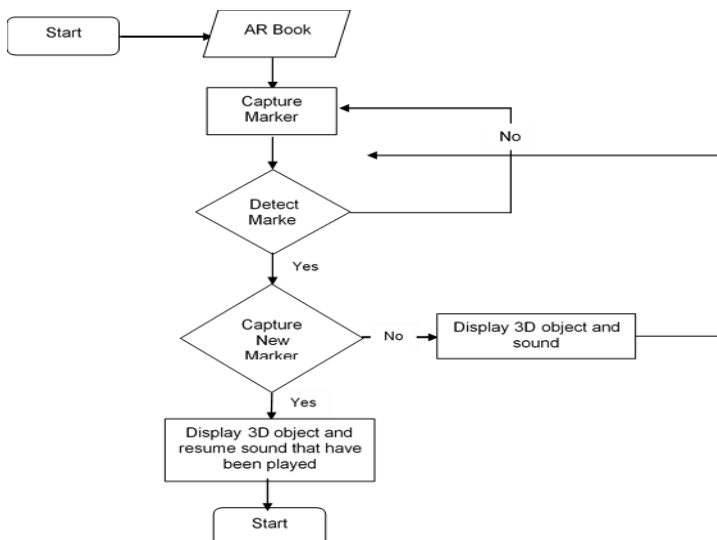
Figure 1. Flowchart Sistem AR

This flowchart is designed to describe the course of AR systems in AR-based mathematical learning models. This design is the basis for creating a prototype AR system, as well as the course of the AR system will be used so that it can project 3D images from books that have been equipped with markers. This design will also determine this system's success when used by special tutors teaching SLD students in inclusion schools.

3.3 Development stage

The use of technology in learning for mathematics students with SLD. Ar-based learning model to overcome the mathematical barriers of students with SLD developed in this study. Use AR that can project images into 3D. This can help students with SLD understand math learning materials. AR development is an AR system consisting of calculated operating materials, fractions, flat builds, and space buildings. The material has used an AR system that allows students with SLD to learn with the help of 3D displayed by AR. The display was developed on ar-based learning models to overcome the mathematical barriers of students with SLD, as follows;

Figure 2. AR System Front View
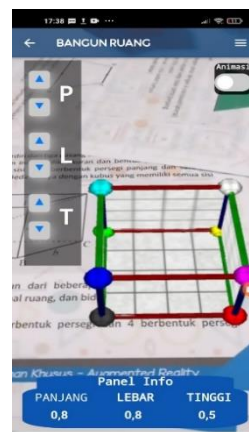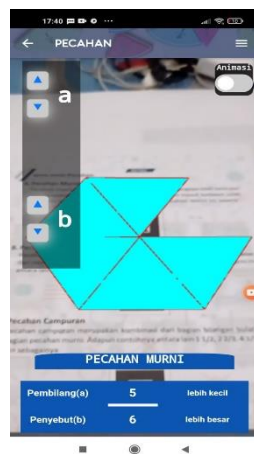

Figure 3. AR System Home Display

Figure 4. 3D Display of AR System

3.4 Validation test by experts

Experts validate augmented Reality-based mathematical learning models to assess augmented reality-based learning models. In this study, researchers appointed experts from Extraordinary Education, Educational Technology, Informatics Engineering, Learning Media, and Language. The results of expert validation are done by filling out the questionnaire as follows:

Table 3. Expert Validation of Augmented Reality-Based Mathematical Learning Models

No	Rating Items	Average Value	Category
1	Learning Aspects	22,4	Excellent
2	Display Aspects	30,2	Excellent
3	Programming Aspects	20,6	Excellent
4	Curriculum Aspects	25,8	Excellent
	Average	**24,75**	**Excellent**

Table 2 shows that the average validation value of expert validation and users of augmented reality-based mathematical learning model seen in terms of learning aspect has an average of 22.4, fall into the excellent category (X > 15.66). The display facet has an average value of 30.2, belonging to the excellent category (21.66 < X). Programming Aspects has an average score of 20.6, belonging to the excellent category (15.66 < X), and Aspects of the curriculum has an average score of 25.8, belonging to the excellent category (15.66 < X). The conclusions obtained from the validation of experts and users of augmented reality-based mathematical learning models show excellent categories.

4. Discussion

The needs analysis results show that it is necessary to develop an Augmented reality (AR) based learning model for learning SLD students in inclusive schools with an average need of 76.25%. The needs of students in learning mathematics are very large where all aspects of life are in the basic material of mathematics (Norris et al., 2019; Salihu et al., 2018). Mathematics learning skills are needed in the future for success in school and work (Hooper et al., 2013). Mathematics learning materials that SLD students need include; operations of numbers, fractions, flat shapes, and spatial shapes, where these materials are generally applicable in daily work (Rodrigues et al., 2019; Wang et al., 2019). Improving math skills utilizing information technology can help complement learning interventions in schools (Soares et al., 2018). The obstacles faced by SLD students in learning mathematics need to be addressed from the start by teachers who teach inclusive classes (Ismail et al., 2019; Noga, 2016).

SLD students show a deficit in the basic understanding of numbers and numbers, which causes difficulties in acquiring mathematical skills (Ihsan Aquil & Mohd. Ariffin, 2020). Special Counseling Teachers take various actions based on their findings in diagnosing students' difficulties in learning mathematics, namely three general cognitive ability domains related to attention problems in students with SLD that may be divided between disorders, namely processing speed, temporal processing, and memory (Moll et al., 2016). Poor performance on these tasks is associated with SLD's poor attentional behaviour. The teacher's unclear delivery of mathematics learning material is one of the factors that cause them to fall behind in classroom learning (Foreman-Murray & Fuchs, 2019). The main action taken by the teacher is remedial in the form of re-teaching (Wijaya et al., 2019). Many teachers also do drills and practice to overcome student learning difficulties (Wijaya et al., 2019). Developing teaching strategies and media appropriate to students' learning difficulties is a small action taken by the teacher (Pua et al., 2021). Another obstacle is that not all special supervisors have competence in developing strategies and learning media that accommodate SLD students (Aro et al., 2019; Lambert et al., 2018).

During the COVID-19 pandemic, it was very clear that teacher learning had good competence and was not in trouble in adapting material to online learning, difficulties in monitoring and evaluating the progress of SLD students in inclusive classes (Supratiwi et al., 2021). The difficulties in online learning during the COVID-19 period have become a reference in developing mathematics learning media that can be accessed anywhere, whether at home or school (Balkist & Agustiani, 2020; Denisova et al., 2020). The use of AR to achieve educational inclusion has not been widely explored (Quintero et al., 2019). A systematic review describes the current situation, where AR as an educational technology needs to be considered for the learning of all students, including SLD students (Quintero et al., 2019). Augmented Reality (AR) is a new technology that can help educators improve their classrooms. With one-to-one initiatives and app development (applications) that create affordable technologies, teachers have more access to innovative support for developing the academic, social, emotional, and behavioural skills of students with disabilities (Carreon et al., 2020). By using AR, teachers can provide multimedia support to help facilitate the learning of SLD students (Carreon et al., 2020). AR can significantly help SLD solve math learning problems such as addition, subtraction, multiplication, subtraction, and spatial construction (Kellems et al., 2020).

AR learning in visual mathematics lessons can help SLD students learn mathematics more meaningful (Miundy et al., 2019; Noga, 2016). Research findings show that students who have difficulty in memory, abstraction, processing, motor and visual perception, use of visual Augmented Reality (AR) technology have a positive impact that can help SLD students learn mathematics more effectively (Alzahrani, 2017; Kellems et al., 2020; Miundy et al., 2019). It should be remembered that spatial intelligence is not an innate skill but a dynamic skill, which can be improved by interacting with real and virtual objects (Del Cerro Velázquez & Méndez, 2021). This ability can be improved by applying new technologies such as augmented reality, which can describe mathematical procedures through pictures and graphs, which greatly helps students visualize, understand, and master concepts related to mathematical functions (Del Cerro Velázquez & Méndez, 2021). This application is designed to display a user interface to make it easier. According to scientific learning, the 3D model is designed to help students mathematically demonstrate the displayed real problems (Sholikah et al., 2015).

Most AR studies in education have considered student learning outcomes and motivations (Cai et al., 2019; Lin et al., 2016). Analysis of results shows that AR applications in mathematics learning can help students with higher self-efficacy pay more attention to higher levels of conception (Cai et al., 2019). Other studies have found that AR can improve children's learning abilities by making the learning process more interactive and enjoyable (Joseph, 2020). With ar boring math learning, this is more fun and interesting for children to improve their math skills (Rebollo et al., 2021). The goal of developing ar-based mathematical learning models is to prepare better students who are at risk of overcoming the barriers to learning mathematics, thus offsetting their classmates' success in public education programs (Wang et al., 2019).

5. Conclusion

The needs analysis results show that it is necessary to develop an Augmented reality (AR) based learning model for learning SLD students in inclusive schools with an average need of 76.25%. The use of technology-based learning media needs to be done to overcome obstacles to learning mathematics for SLD students during the Covid-19 period. Augmented reality is one solution based on its users, which can create 3D visual displays. The design of an AR-based mathematics learning model can increase the motivation and learning outcomes of SLD students. AR makes it easy to explain the abstract material and tends to be boring in mathematics learning material to understand the material easily, effectively, and fun. The development of the mathematical learning model in this study needs to be carried out on

learning materials that SLD students find difficult, including; operations with numbers, fractions, flat shapes, and space constructs. The material is very close to people's lives and daily work, so it needs to be understood by SLD students. Tests on the development of AR-based mathematics learning models have been validated by experts, including in the very good category (24.75). Special assistant teachers can use AR-based mathematics learning models in learning mathematics in inclusive classes with SLD students. The goal of developing an AR-based mathematics learning model is to better prepare at-risk students in overcoming barriers to learning mathematics, thereby compensating their classmates to succeed in general education programs.

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