The development of mathematics teaching materials integrating by Augmented Reality Software and Android for deaf students

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Abstract. Mathematics has a unique concept and context, so mathematics is not easy to learn. Many students find it difficult to understand about mathematical concepts especially for students who has physical disability, such as hearing impairment. Teaching materials is required in mathematics learning, especially the topic of angles. One of the teaching materials on the topic of angle is developed using the integration of augmented reality (AR) software and android. The aims of this research are to describe the development phases and to describe the evaluation result of the teaching material integrated by AR software and android. This research uses the development (R&D) method by adapting and modifying the steps of R&D used by Borg and Gall. The sources of the data and information in this research is an expert in deaf education, a media expert, a mathematics teacher and a seventh-grader deaf student at a Junior High School of inclusion in Bandung. The result of this research shows that the teaching material integrating by AR software and android for deaf students is very good based on the referred category. It can be used in learning mathematics in school.

1. Introduction
Mathematics is an exact science that is used in other fields of science as a basis for its calculations, therefore it is very important to learn mathematics. Mathematics has a unique concept and context, so mathematics is not easy to learn. Many students has low-ability to understand mathematical concepts [1]. The concepts in mathematics are interrelated and they are useful for problem-solving in daily life. Mathematics is important as a tool, as science (for scientists), as a form of attitude and as a guide to mindset [2]. Based on the importance of mathematics in daily life, mathematics needs to be understood and mastered by all levels of society, especially by students in schools, including deaf students.

Deafness is a term used to refer a child who has a disability in the sense of hearing. usually, people who can't hear, can't speak too. Language skills can affect cognitive abilities and also affect the abstraction skill in deaf students, so their abstraction skill is still low. Thus deaf students will have difficulty accepting abstract lessons such as mathematics [3].

In general, deaf students has many obstacles in learning activities. One of the internal obstacles experienced by deaf student is in the form of hearing and communication barriers, resulting in low academic achievement. People with hearing impairment use verbal language, sign language, and body language in learning [4].
The problem of learning mathematics in special school is very complex. Mathematics is one of the fields of study that is deemed difficult by deaf children because it has a connection with the mastery of language, symbols, terms that have their own meanings and abstract nature [5], [6]. Deaf students experience difficulties in mathematics especially in problem solving and measurement [7]. Previous research findings related to the learning of deaf students prove, the low mathematical achievement of deaf students compared to other students at their age [8], [9]. Deaf students tend to have difficulty in interpreting words and sentences. It was identified in the results of observations in a special school for deaf students in Bandung, that is: deaf students had difficulty in solving word problems in the arithmetic field which contains more than 20 words, difficulty in finding effective language in interpreting specific terms and symbols. In addition to these difficulties, in general, mastery of basic competencies is still low or does not meet individual learning completeness criteria, and the teaching materials were dominated by verbal [6].

One of the basic mathematical competencies for students in special schools for deaf students is to identify angles and types of angles (right angles, acute angles and obtuse angles). In teaching deaf students who lack of vocabulary in communication, a special education teacher must be clear and consistent in using vocabulary when delivering materials. This is because children with hearing impairment have very little or no response to sound. The 2016 thematic book that is still used by 8th grade students in special schools for deaf students tends to contain too many narrative sentences in explaining the concept of materials. This can make students feel tired in learning, because deaf students are visual learners who rely heavily on visual information [9], [10]. Therefore, deaf students need teaching materials and learning media that are appropriate to their characteristics and needs.

Teaching materials are materials used by teachers or instructors in carrying out teaching and learning activities [11]. Teaching materials are a set of materials that contain learning materials or content that are designed to achieve learning objectives [12]. By applying mathematics teaching material, student activities can be increased [13]. The development of teaching materials should pay attention to the principles of learning such as the following: (1) starting from easy to difficult to understand, from concrete to abstract; (2) repetition reinforces understanding; (3) positive feedback gives reinforcement to students’ understanding; (4) high motivation is one of the determining factors for success in learning; (5) achieving goals; and knowing the achieved results [14].

Information and communication technology (ICT) are needed to solve problems in mathematics that can’t be solved by human hands [15]. The integration of ICT in mathematics education can improve students’ motivation and increase students’ participation, individually and actively, in the discovery of mathematical concepts and topics [16]. Utilization of ICT in mathematics learning is expected to support the learning process according to the 2013 curriculum which includes: observing, asking, processing, reasoning, presenting, concluding, and creating or deciding.

A technology that can be used as an alternative to help the process of learning mathematics is Augmented Reality (AR) [17]. AR is a technology that combines two-dimensional or three-dimensional virtual objects into a real three-dimensional environment and then projects virtual objects in real time [18], [19]. Virtualization of learning media using augmented reality can display animations in 3D. With the process, the user uses an application that will do a marker scanning, after the marker is recognized according to the reference data in the system application, the application can display 3D images on the android screen [20]. Augmented Reality can be used in the learning process as an instrument of learning mathematics to attract students’ interests and help them understand the contents of geometry [21].

In this research, AR software will be implemented as a teaching material for deaf students using Android that will help deaf students in learning mathematics and mastering basic competencies, especially in angle topic. This study aims to create angle teaching material integrated by augmented reality software and android for deaf students, with the following details: (1) describe the stages of developing a teaching material about angle integrated by augmented reality software and android for deaf students; and (2) describe the evaluation results of the angle teaching material integrated by
augmented reality software and android for deaf students. This teaching material is adapting the mathematical basic competencies for deaf students.

2. Method

This study uses a research and development (R&D) method by Borg & Gall [22]. We adapted and modified the R&D stages that are used, namely: (1) the design phase, where the teaching material, AR software, and assessment instruments are compiled for validators, which are a deaf education expert, a media expert, and a teacher of a special school for deaf students; (2) the development phase, where teaching material and AR software is assessed by the validators, then they are revised according to the experts’ advice; and (3) the evaluation phase, where the teaching material were tried out to a seventh-grader deaf student at a junior high school of inclusion in Bandung in the 2017/2018 academic year. It was intended to find out the readability of the teaching material and the ease of using AR software and android. The mathematical teaching material developed are adjusted to the basic competencies on the topic of angle material that has been set in the 2013 Curriculum of special schools for deaf students in Indonesia. The teaching material created in this study is in the form of an integrating AR module.

The research instrument used was an assessment sheet of the teaching material integrated by AR software and Android for the validators. The teaching material evaluation sheets in the form of a questionnaire, a suggestion sheet, and a conclusion sheet of feasibility of the teaching material are processed and analyzed. The questionnaire uses a Likert scale with a choice of answers, namely “Strongly Agree”, “Agree”, “Disagree” or “Strongly Disagree”. In the process, each criterion of a positive statement is changed into a scale weight of 5, 4, 2, 1. While each criterion of a negative statement is changed into a scale weight of 1, 2, 4, 5. Then calculated using Rating Scale [23] follow:

$$p = \frac{\text{Data collection score}}{\text{Ideal score}} \times 100\%$$

Notes:

- $p$ : percentage score
- Ideal score : highest score × number of respondents × number of items

The validity level of the teaching material in this study are grouped into four categories using the following scale [24].

| Percentage score | Interpretation |
|------------------|---------------|
| $0 \leq p < 25$  | poor          |
| $25 \leq p < 50$ | fair          |
| $50 \leq p < 75$ | good          |
| $75 \leq p \leq 100$ | very good   |

3. Results and Discussion

The results and discussion of the research are in accordance with the stages of research using the Research and Development (R&D) method, which is based on research procedures that have been planned. The design phase includes: (1) the information and collection stage, at this stage the literary and field study activities are carried out, then we obtained the information on the characteristics of deaf students and the teaching material used; (2) planning stage, at this stage, we carried out the preparation of the related material using augmented reality software technology; (3) design of preliminary Augmented Reality, at this stage AR software design is obtained through a flowchart and module design via storyboard as follows:
The storyboard is designed to relate between Modules and AR Software. The module was designed by loading several pages consisting of the front page/cover, the user manual page, the concept map page, the material page.

The development phase includes: (1) preliminary Augmented Reality development phase, in this stage the marker/QR code, database, 2D or 3D object, and AR software-based animation are made. Then the initial product obtained is mathematics teaching material about angle integrated by AR software and Android; (2) preliminary field-testing phase, at this stage assessment and improvement suggestions are given by experts consisting of a deaf education expert, a media expert, and a teacher of a special school for deaf students. The content related to mathematical material was obtained through mentoring activities with an advisor.

The validation results by the expert and the teacher of the product development of the angle teaching material integrating by Augmented Reality software and Android that have been compiled are as follows:

**Graph 1. Teacher and expert Assessment.**

Based on the validation results of the questionnaire assessment by the deaf education expert, the media expert and the teacher as a practitioner, it can be concluded that the validity level of the teaching materials about angle integrating by AR software and Android is very good. The mathematics teaching materials for the achievement of mathematical basic competencies of deaf students did not require a total overhaul.

The suggestions and recommendations from experts and practitioner who validated the mathematics teaching material about angle integrating by AR software and Android are as follows: (a)
add individual assignments to each sub-material to give students the opportunity to try to follow the steps in the explanation of the material or example; (b) adjust the use of examples in the form of images in the module with objects contained in AR software based animations; (c) complete the installation guide page on the module; (d) specify the use of button labels such as "pause" according to the purpose or function of the button; (e) to a short animation, add a description or button to play back, so the user knows that the content contains animation; (f) increase the images in the module; (g) change the subtitle of the learning experience to the learning objectives on the cover page; (h) the maximum number of words used for each line is seven words; (i) pay more attention to the effective use of sentences; (j) font size in module is 14 and use the Arial font style; and (k) need to explain some terms that are not yet known to students with hearing impairment; (3) main product revision phase, at this stage revisions were made according to the assessment and suggestions for improvement from experts and special school teacher for deaf student. The display of some materials and animations in AR software (after revision) is presented below.

Figure 2. Front cover display.
Petunjuk Penggunaan Augmented Reality Software

Menggunakan Android

1. Download Augmented Reality Software pada link download berikut http://bit.ly/2FJC5Su.
2. Install aplikasi AR_Sudut.apk yang telah di download pada android.
3. Setelah selesai menginstall, buka aplikasi tersebut.
4. Secara otomatis kamera android akan menyala.
5. Untuk melihat Augmented Reality Software arahkan kamera sehingga dapat memindai marker pada modul.
6. Lakukan hal yang sama untuk setiap marker yang terdapat pada submateri sudut.
7. Dalam satu marker terdapat beberapa scene. Untuk melihat scene yang lain, tekan tombol yang tersedia sesuai pilihan.

Figure 3. Concept map page.

Figure 4. Installation and usage instructions page for AR software.
Mathematics teaching material about angle integrating by AR Software and Android have been revised as suggested by experts. The mathematics teaching material is declared feasible to use in angle learning for deaf students. The product was then tested on a deaf student. This was done to obtain information about the readability of the teaching material and the ease of using AR software and
android. Learning activities using the mathematics teaching material about angle integrating by AR software and android as follows:

In Figure 7, a student was guided when using the module teaching material. The module used the integration of AR software and android. This module about angle learning consisting of activities such as recognizing angles and their elements, measuring angles, drawing angles, and identifying the types of angles. Student can directly operate AR software and android by her/himself. The student that used the AR software did not need a long time to learn.

Figure 7. Use of the angle teaching material integrating by AR software and Android.

In Figure 8, after using the angle teaching material integrating AR software and Android in the sub-material to recognize angle, the student defined angles by drawing straight angles using no sentences. It is assumed that this straight angle was obtained from the visualization shown in AR software.

Figure 8. Activities of student completing practice questions.

In Figure 9, the student was able to measure the angles available in the practice questions with a number of different angular positions.

Figure 9. The Student measure angles.
In Figure 10, the student looked enthusiastic in watching the animations contained in the AR software. It can be said that the mathematics teaching material about angle integrating by AR software and android greatly motivate students to learn material about angles.

![Image](https://example.com/figure10.png)

**Figure 10.** The Student observe animations in AR software.

4. Conclusion

The teaching mathematics material about angle integrating by AR Software and Android are considered very good and feasible by material expert, deaf education expert, media expert, and field practitioner. This product can be used as a mathematics teaching material in eighth-grade classes in special school for deaf students or in third grade in the elementary school. Based on the results of the teaching material testing to a student, it is found that students enjoyed learning with the mathematics teaching material about angle integrated by AR software and android. The student was also able to solve practice questions related to recognizing angles, measuring angles, drawing angles, and identifying the types of angles. The student also had motivation in learning the angle material. The mathematical teaching material integrating by AR software and android is an alternative to help students visualize the learning of the material concept. It can create a learning that can foster students’ motivation because it involves technology in the modern era.

The mathematics teaching material about angle integrating by Augmented Reality Software (AR Software) and Android can help bridge the process of deaf students' abstraction in learning mathematics. The media of Augmented Reality Software (AR software) and Android is better applied to geometry materials. The characteristic of AR software is to bring up a 2D or 3D object on top of a marker. It is recommended only as visualization.

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