Developing Bismath: Sign Language Digital Dictionary of Mathematical Symbols for Deaf Students in Higher Education

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Abstract. Students with special needs have the right to obtain proper education and adequate learning facilities. Deaf students often face difficulties translating mathematical symbols they must learn from a mathematical course. This research and development (R&D) research aims to produce a product in the form of a mathematical symbol sign language dictionary for deaf students in higher education. The development design is a unified modeling language (UML) that includes preparing use case diagrams, activity diagrams, sequence diagrams, and class diagrams. The development method is design research, including the preliminary, prototyping, and assessment stages. The resulting product is an android application that can translate mathematical symbols in written form into sign language in video format as an output. The product is validated by mathematics, sign language, and learning media experts. The product was tested on 15 deaf students in courses that use mathematical symbols. The test results show that the product is suitable for use and meets valid, practical, and effective criteria. This product can facilitate the problem of translating mathematical symbols between lecturers and deaf students in higher education.

Keywords: Deaf, sign language, mathematics

1 Introduction

Students with special needs are students who have obstacles to participating in the lecture process due to physical, emotional, mental, and social disorders, so they need special aids, environmental modifications, or appropriate alternative techniques so that they can attend lectures optimally with the hope that in the future students with special needs can participate fully and productively in social life.

Implementing education for students with needs in higher education is essential because the presence of children with special needs contributes to developing a better university. After all, it requires transformational practices and developing attitudes and actions sensitive to special needs students' conditions (Weedon & Riddell: 2016). In addition, for students with special needs, the university is an opportunity, an empowering experience, and is considered a vehicle to improve their quality of life (Martins., Morges., & Gonçalves, 2018; Gibson, 2015). The implementation of special education

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in higher education for students with special needs cannot be separated from the joint commitment of the world's citizens about education for all (Education for All), as stated in The Salamanca Statement. Namely, students with special needs must have access to education that can accommodate them in pedagogy. Student-centered (The Salamanca Statement, 1994).

One of the categories of students with special needs in higher education is students who are deaf. Deaf students experience hearing loss, resulting in their limitations in communicating and obtaining linguistic information through the sense of hearing. Therefore, in communicating, deaf students generally use sign language, lip reading, or even total communication. From the data obtained by the Directorate of Learning at the Ministry of Research, Technology and Higher Education, it was recorded that there were 401 students with special needs spread across 152 universities in Indonesia, and among them were deaf (Belmawa, 2017).

Status as a student is indeed a matter of pride for deaf students because they can continue their tertiary education to develop their academic potential. But on the other hand, their hearing and communication limitations are obstacles to learning interactions in the classroom. Especially the communication interaction with the course lecturers. As a result, there is often miscommunication between the course lecturers and the deaf students. Based on interviews with deaf students, information was obtained that deaf students had difficulties when they wanted to communicate mathematical symbols in sign language to the course lecturers.

On the other hand, some lecturers who teach courses do not understand how to communicate mathematical symbols in sign language. This phenomenon occurs, among others, in Inferential Statistics, Education Evaluation, and Nonparametric Statistics courses, where in these courses, many use mathematical symbols in the form of numbers, numbers, or other mathematical symbols. This is undoubtedly a problem that must be immediately sought for alternative solutions.

One alternative solution to overcome the above problems is to use technology that can help deaf students and lecturers jointly use sign language as a form of communication in learning interactions in the classroom. For this reason, assistive technology (assistive technology) is needed to provide a means of communication that can translate words, texts, numbers, numbers, and other mathematical symbols practically and efficiently to support the effectiveness of the learning process in inclusive classes at universities.

Departing from this, it is necessary to develop learning innovations and assistive technology for students with disabilities in the form of an Android-based Mathematical Sign Language Dictionary Application for students with hearing impairments in universities. The application can be a communication tool for deaf students and lecturers so that interaction in class learning becomes more effective. The functional specifications of the mathematical sign language dictionary application for students with hearing impairments that will be developed include: (1) The digital mathematical sign language dictionary application can perform sign language search functions for mathematical symbols and text via smartphones; (2) The application of a digital mathematical sign language dictionary can display the translation of words, numbers, numbers, and arithmetic into sign language (SIBI); (3) The application of a digital mathematical sign language dictionary is designed on a mobile basis using Andriod software; (4) The application of the digital mathematical sign language dictionary is designed by taking into account the elements of practicality, effectiveness, usability, safety, convenience, and independence of its users; and (5) The application of a digital mathematical sign language dictionary that can not only be used by deaf students but can also be used by educators/lecturers and the general public who want to learn sign language.

2 Literature Study

2.1 Education for Students with Special Needs Special

Education is an educational program specifically designed to meet the needs of children with disabilities or commonly known as disabilities (Wilmshurst & Brue, 2005, p. 3). A child is said to be a student with special needs if he has learning difficulties. The learning difficulties experienced are more due to physical and mental disabilities. In more detail, it was revealed that the category of students with special needs, if they have the criteria, namely (1) having considerable learning difficulties compared to children their age; (2) have a disability that prevents them from using the facilities available in public schools; and (3) already at the age of compulsory education but these students are classified in points 1 and 2 (Row, 2005: 18). From some of the definitions above, it can be understood that education for students with special needs is an educational program specifically designed to meet the needs of students who have learning difficulties caused by physical and mental abilities and students who have superior intelligence and talents.

The education program for special-needs students was first started in 1975 called the Education of All Handicapped Children Act (EHA). Then in 1990, it changed its name to the Individuals with Disabilities Education Act (IDEA). IDEA 2004 later developed into an international organization that aims to protect the rights of students with special needs or disabilities to obtain equal educational opportunities. IDEA (2004) notes that there are ten categories of students with special needs, namely: (1) having mental retardation; (2) hearing loss; (3) speech disorders; (4) visual impairment; (5) emotional severe disturbance; (6) orthopedic disorders; (7) autism; (8) traumatic brain injury; (9) other health problems; and (10) specific learning disabilities (Wilmshurst & Brue, 2005, pp. 11-12). In contrast to IDEA, Chinn (2010: 15) states explicitly that students who are categorized as students with special needs consist of six categories, namely ADD/ADHD, autism, dyslexia, dyspraxia, hearing and speech disorders, and students with psychological disorders. In another part, Chinn (2010: 26-27) explains that deaf students or students who experience hearing loss and hearing difficulties also tend to have difficulty speaking. However, this is not generally accepted. Deaf students with hearing and speaking problems are usually a disorder because they are congenital. However, some students are deaf and only have hearing problems without experiencing speech problems. In conditions like this, usually, the cause of the hearing loss experienced by the deaf student is an accident that results in impaired hearing function.

The objectives of implementing education for students with special needs are: (1) to develop students' knowledge, experience, and understanding. With this development, there will be students' awareness of moral values; (2) so that students with special needs can contribute to society, have a sense of responsibility, and have independence after taking formal education (Dean, 1996, p. 4).

2.2 The essence of Deaf Students

Hearing is the ability to detect mechanical vibrations called sound. Hearing loss is commonly known as deafness or deafness. Some experts define deaf students from various perspectives. Batshow (1997: 247) stated that "from a medical perspective, the definition of deafness is mainly based on the degree of hearing loss, and most audiologists attribute it to the profound range of hearing loss (hearing sounds only above 90 dB)". From the statement above, it can be understood that from a medical perspective, deaf students are students with a deep level of hearing loss, namely, the sound of hearing is only above 90 dB. If viewed from a socio-cultural perspective, Deaf students can be defined as part of a linguistic and cultural minority who communicate in their own language (sign language) and have a culture and tradition that is different from the majority of hearing normal children (Marschark, & Hauser, 2011: 4). Meanwhile, the Individuals with Disabilities Education Act (IDEA, 2004) defines deaf students as students with hearing loss severe enough that it can limit an individual's opportunity to process linguistic information through the sense of hearing, even when amplification or hearing aids are used (Kirk, Gallagher, Coleman, & Anastasiow, 2012: 296).

Based on some of the opinions of the experts above, it can be concluded that deaf students are students who experience hearing loss (ranging above 90 dB) which results in their limitations in communicating and obtaining linguistic information through the sense of hearing. Therefore, in communicating, deaf students generally use sign language.

2.3 Classification of Deaf Students

There are several classifications of deaf students. Sharon, Christi, & Vammen (2000: 4) classify deaf students based on their level of hearing loss into four categories, namely *(1) Deaf students; (2) Hard of Hearing students; (3) Residual Hearing students; and (4) student audiogram.* It was further explained that:

1) ***Deaf*** refers to hearing loss that blocks the processing of information or sound even though a hearing aid is in use. A person called 'Deaf' usually has severe hearing loss (over 90 dB) and is pre-language.
2) ***Hard of Hearing*** refers to hearing loss that does not entirely prevent practical communication through speech. Thus, people who are hard of hearing usually communicate by using speech. Hearing is usually done using a hearing aid or utilizing residual hearing. Someone who is classified as hard of hearing can process linguistic information well through audio.
3) ***Residual hearing*** refers to the hearing that remains after a person has a hearing loss. It is stated that the greater the hearing loss, the less residual hearing.
4) ***An audiogram*** is a graphic representation of what the person can and cannot hear. This is a graphical display of the hearing test.

In general, the classification of the hearing loss level of deaf students according to Sharon, Christi, & Vammen (2000: 16) can be seen in the following table.

Table 1. . Classification of Hearing Loss in Deaf Students

No.	Level of hearing loss Hearing	range (dB)	Criteria
1.	*Mild*	26-40	1) there are some parts of words missing in communication. This level of impairment is still able to speak; (2) errors such as difficulty in articulating the letter "a" for the letter "k"; and (3) less severe hearing loss.
2.	*Moderate* (moderate)	41-55	(1) has difficulty communicating; (2) if they do not use assistive devices, they may mispronounce and have limited vocabulary; and (3) have difficulty following verbal instructions.
3.	*Moderately severe*	56-70	1) reduced access to oral information; (2) without using hearing aids, children will find it very difficult to understand others; (3) speech and language difficulties; (4) have a different voice quality, i.e., they can speak in a high or nasal tone.
4.	*Severe*	71-90	1) unable to speak fluently; (2) if they use hearing aids, and they are likely to make speech errors; (3) difficulty in understanding other people, which may lead to avoidance of communication with others; (4) difficulty reading and writing.
5.	*Profound* (very severe)	> 90	(1) unable to speak fluently; (2) can read lips; (3) use sign language.

2.4 Communication System for Deaf Students

The World Bank Group organization, which is engaged in global educational practice for children with special needs (2015: 71), explains that there are two types of philosophies of communication methods developed for deaf students. The two philosophies are oralism and total communication.

Oralism (oral)

The philosophy that wants to develop verbal language in deaf students through the auroral mode is called oralism. The communication approach used in this philosophy is Emphasis on Speaking (Emphasis on speaking). Students who come from an Oralism background use the auditory (listening) modality. They are also called verbal or verbal students as they speak. In addition, some of them also talk and read lips. Hearing loss in these deaf students will be identified early, and they will be equipped with good-quality hearing aids or cochlear implants at an early age. Their parents will try to teach them to speak and read at a young age. There are two methods in this approach, namely Auditory/Oral and Auditory-Verbal.

The Auditory/oral method emphasizes hearing-impaired students to listen through the use of hearing aids and the proper techniques that support the development of audition and spoken language. Some hearing/oral educational therapy programs also have a vital visual component. In other words, there is an emphasis on using visual techniques to teach them to speak orally. In some cases, reading (lip) skills are used instead of hearing.

The Auditory-Verbal method is similar to the Auditory/oral approach in that there is a strong emphasis on maximizing the child's residual hearing and ability to use it. Its main objective is to provide adequate support for the child's development and integration of the language that is heard and spoken into everyday life. The Auditory-Verbal approach also supports children's participation in regular classroom placements,

Total Communication The

the philosophy that combines all communication tools, including speaking, lip reading, and sign language, is referred to as total communication. The approach used in this philosophy is Emphasis on communication (Emphasis on communication). Unlike Oralism, Total Communication (TC) follows an oral approach of doing whatever is best for the child and emphasizes communication in any form. It supports the use of all communication modes and languages as needed in different contexts. The purpose of this philosophy is to provide deaf students the opportunity to use all the strategies necessary to support their communication and language development. There are two methods, namely Fingerspelling (spelling letters) and the Signed system (sign language).

Fingerspelling is a method of spelling each letter using hand and finger movements. Fingerspelling is used to spell people's names, place names, and for some types of words that do not have a sign symbol. Besides that, it is also used to clarify gestures that are not recognized by the person reading the sign.

A signed system (sign language) is based on verbal language in which each word is assisted by a separate sign. It is used together when spelling words. Therefore, this system is referred to as Simultaneous Communication (SimCom). Deaf students must speak when gesturing.

3 Method

In order to obtain assistive technology that meets the valid, practical, and effective criteria, the method of developing assistive technology for the application of an Android-based digital mathematical sign language dictionary uses the Design Research development method (Akker, et al. 2006); (Akker, Plomp & Nieveen, 2013). Design Research is a development research method that aims to design and develop interventions such as learning technologies, learning programs, products, and the like as solutions to solving educational problems as well as to advance knowledge about the characteristics of interventions. In Design Research, a development product is said to be feasible to use if it meets the valid, practical, and effective criteria (Akker, Plomp & Nieveen, 2013: 29). In the Design Research development method, the stages of implementing research and development include (1) preliminary research, (2) prototyping stage, and (3) assessment stage.

4 Result and Discussion

4.1 Preliminary Research

The preliminary research stage is a preliminary research activity. At this stage, a needs assessment will be carried out in the learning process/lectures for deaf, disabled students, learning barriers, as well as conducting an analysis related to assistive technology that can be developed to overcome the obstacles experienced by these deaf, disabled students. To obtain assistive technology that meets the criteria of validity, practicality, and effectiveness, literature analysis and studies related to previous studies in the field of assistive technology will be carried out for students with hearing impairments. The results of these previous studies will be the theoretical basis for developing assistive technology.

The first stage is an analysis of the need for mathematical symbols. Learning mathematics often uses many symbols in its operation. For example, the symbols plus (+), minus (-), times (x), divide (÷), squared, equal to (=), more than (>), square root, brackets, and others. In mathematics learning, there are symbols that are very often used in basic and advanced mathematical operations. As an initial step, an analysis of the symbols that will be included in the sign language dictionary of mathematical symbols is carried out. The determination and selection of these symbols are carried out by considering the high and low frequency of using symbols in all mathematical material given to students.

The next stage is the analysis of the mathematical learning needs of deaf students. Data regarding the mathematical learning needs of deaf students were obtained through interviews. Interviews were conducted on deaf students in the Bogor area of West Java and in the Yogyakarta area. Based on the results of the interview, here are some important notes obtained related to the conditions of learning mathematics in universities.

1) Deaf students who attend special schools (SLB) receive curriculum adjustments at the elementary and middle school levels, which have an impact on differences in the achievement of essential competencies that must be mastered by deaf students with regular students. Deaf students are required to master learning outcomes 2-3 levels below regular students. However, when in college, there is no difference in the demands for learning outcomes for deaf students and regular students. This causes deaf students to be overwhelmed by the differences in the achievement of competencies that must be mastered the same as regular students
2) . Most students think that mathematics or mathematical material is challenging to understand.
3) Universities have not facilitated equalization of learning materials between deaf students and regular students before lectures begin.
4) Universities have not yet prepared a particular service unit for deaf students.
5) There is no sign language for mathematical symbols used in learning.

4.2 Prototyping Stage The

the prototyping stage is the stage where researchers design and design the assistive technology to be developed. Sign language formulation for mathematical symbols to be included in the product. Language is an agreement in a community, and so is sign language. So to formulate a sign language for certain mathematical symbols, an agreement is needed in a community. In the implementation of the development of this assistive technology, one by one, the mathematical symbols were discussed and agreed on what the sign language would look like for the symbol. At this stage, an online Focus Group Discussion (FGD) was conducted, which was attended by discussants from inclusive learning experts, speakers from the Indonesian Sign Language Center (Pusbisindo), and discussants from Gerkatin, and attended by deaf students. The FGD discussed the agreement of sign language for mathematical symbols as formulated in the previous section. The discussant first displays the symbol that will be translated into sign language by providing an explanation of the meaning of the symbol. Through this FGD, it was agreed that the sign language for the mathematical symbols had been determined.

The assistive technology produced in this development research is an Android-based mathematical sign language dictionary application accompanied by a user manual. The Assistive Technology Development Design is based on the Unified Modeling Language (UML) design which includes:

1. Use Case Diagram.

Use Case Diagrams describe the interaction between application users (users) and use cases that are adapted to the specified scenario. The Android-based mathematical sign language dictionary application will be developed as a use case, as shown in Figure 1 below.

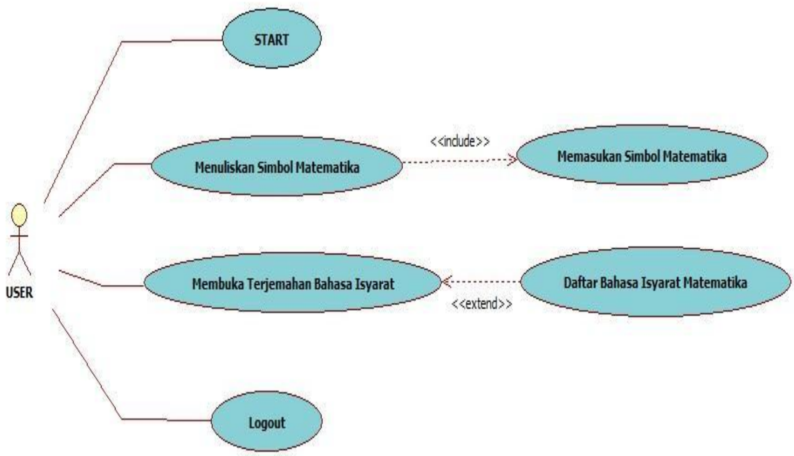

Fig. 1. Use *a case* diagram of a digital mathematical sign language dictionary

Figure 1 above illustrates a series of activities that can be carried out by users of the system. A user can perform operations/activities such as starting a search on the start, writing mathematical symbols (or text), opening translation results, and ending the search on the logout. The dotted line or the line "<<include>>" and <<extend>>" indicates the information obtained in accessing the menus in this dictionary application.

2. Activity Diagram

The activity diagram describes a flow diagram of activities in the application system to be developed. The activity diagram of the Android-based mathematical sign language dictionary that will be developed can be seen in Figure 2 below.

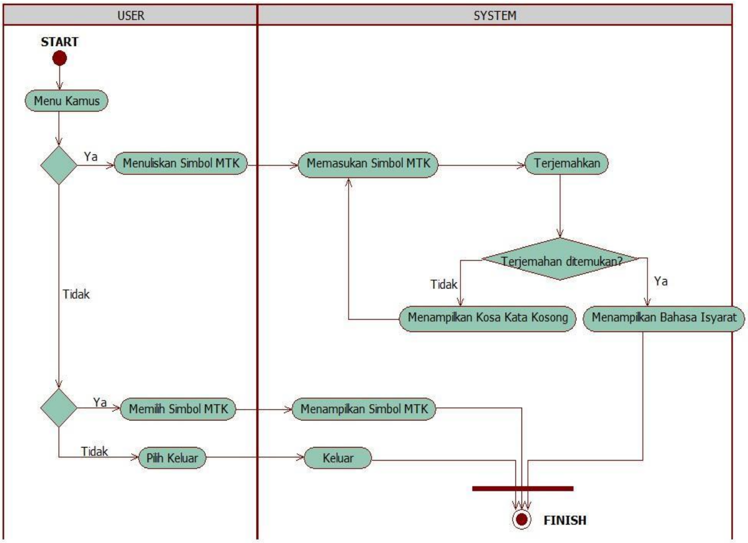

Fig. 2. Diagram of the Android-based mathematical sign language dictionary

Figure 2 above illustrates the flow of the system of a series of activities that can be carried out by the user in the mathematical sign language dictionary application. The main activities that can be done by users in this application include the translation of mathematical symbols in the form of numbers, numbers, and text into sign language.

The user starts the activity by going to the main menu of the application. After entering the main menu, the user will write down mathematical symbols or text or choose mathematical symbols that are already available in the database, which will then be translated into sign language by the system. The system will automatically display the results of the translation into sign language. If the translation is successful, the user can return to the main menu to perform other translation activities or end the search (logout). However, if the translation is not successful because the user made a mistake in writing the mathematical symbol, the user will be directed back to the main menu to write the mathematical symbol correctly and re-translate it.

3. Sequence Diagram

A sequence diagram is a diagram that describes the sequence of the translation system contained in the application to be developed. Sequence diagrams of the Android-based mathematical sign language dictionary can be seen in the following figure.

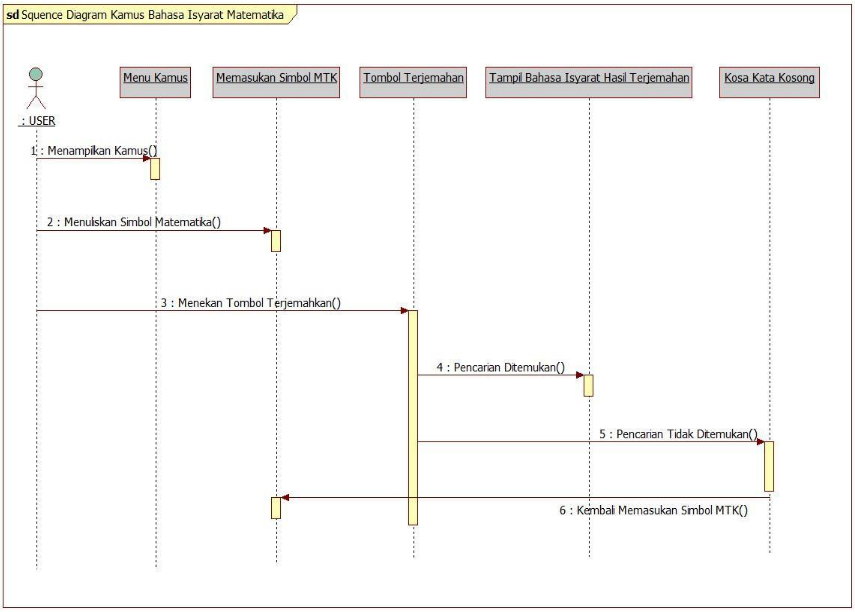

Fig. 3. Sequence diagram of digital math sign language dictionary

In Figure 3 above, it can be explained that the user will first enter the main menu. The feature that will be seen by the user when on the main menu is the "start," which indicates the user will start searching for sign language translations. After clicking the start button, the user will be redirected to the "write math symbol" and/or "choose math symbol" screen. After the user writes the mathematical symbol or text to be translated, the user will press the translate button, which then the system will translate and display the results of the translation into sign language. If the search for translation results is not found, the system will display empty vocabulary, which means that it requires the user to return to the menu to enter mathematical symbols/text.

4. Class Diagram

The class diagram is a diagram that shows the existing classes of an application system and their logical relationship. In addition, Class diagrams also describe the static structure of an application system. The class diagram of this Android-based mathematical sign language dictionary can be seen in the following figure.

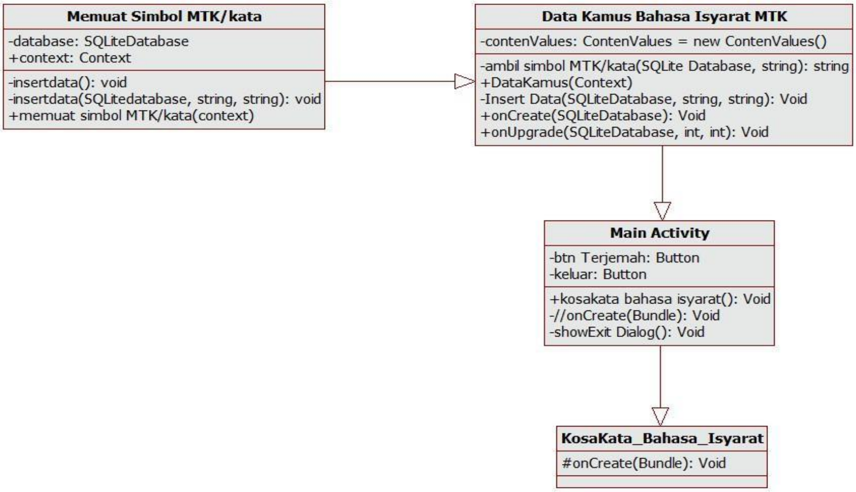

Fig. 4. Class diagram of a digital mathematical sign language dictionary

Figure 4 above shows the relationship between classes in the digital mathematical sign language dictionary application system that will be developed. There are four classes in this application system, namely: (1) containing mathematical symbols or text; (2) database mathematical sign language dictionary(3) play activities; and (4) sign language vocabulary. The class “contains mathematical symbols or text” is related to the class “database mathematical sign language dictionary. This is because the system will code the search for sign language translations of mathematical symbols or text written by the user based on the database of the sign language. Meanwhile, the class "database of the mathematical sign language dictionary” is related to the class “main activity” as the caller for translation through the button feature. The "main activity" related to the "sign language vocabulary" class as a viewer of the system translation results. The following is a display of the developed product.

The menus available on Bismath are Glossary, Dictionary, Contacts, and About. The following is an explanation for each of the available menus.

1. The glossary contains a list of mathematical symbols along with their meanings and examples of their use. This menu is expected to make it easier for users to understand the meanings of mathematical symbols that are often used.
2. The dictionary contains a sign language bank of mathematical symbols. Users can enter input in the form of text to find the sign language of the intended mathematical symbol. Or, the user can simply select the symbol image available in the dictionary menu to find out the sign language for the symbol. Sign language is then displayed in the form of a video.
3. Contacts contain contact data that users can contact if they want to make further correspondence to Bismath developers.
4. About contains product descriptions and profiles from the development team.

Bismath can be operated on mobile devices with the Android operating system through the installation of files with the apk extension. The apk file size for Bismath installation is 34 Mb. Bismath can be operated on Android devices on a minimum version of Android Froyo with a minimum RAM capacity of 1 GB.

4.3 Assessment Stage The

assessment stage is the stage where the researcher conducts field trials and tests the practicality and effectiveness of the developed assistive technology. This stage is also known as a limited field trial. Field trials are used to determine the feasibility of the product to be used after passing the validation stage. Field trials were carried out in Yogyakarta. Aspects that are assessed in this test are appearance, readability, use, and usefulness.

Practicality and effectiveness tests were carried out by implementing assistive technology, which was developed for eight students with hearing impairment in Yogyakarta in the courses (1) Inferential Statistics; (2) Educational Evaluation; and (3) Nonparametric Statistics in the 2021-2022 academic year. The results of the trial show that the product can be used effectively in the implementation of mathematical learning. The product can not only be used by Deaf students but can also be used by non-disabled students as a medium to help communicate with the Deaf.

5 Conclusion

This is a research and development (R&D) research that aims to produce a product in the form of a mathematical symbol sign language dictionary for deaf students in higher education. The development design is a unified modeling language (UML) that includes the preparation of use case diagrams, activity diagrams, sequence diagrams, and class diagrams. The development method is design research, including the preliminary research stage, prototyping stage, and assessment stage. The resulting product is an android application that can translate mathematical symbols in written form as an input into sign language in video format as an output. The product is validated by mathematics learning experts, sign language experts, and learning media experts. The product was tested on 15 deaf students in courses that use mathematical symbols. The results of the test show that the product is considered suitable for use and meets the criteria of being valid, practical, and effective. This product can facilitate the problem of translating mathematical symbols between lecturers and deaf students in higher education.

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