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SMART-AR: Multimodal Smart Pop-Up Book Based on Augmented Reality with Braille-Voice Over as a Support for Inclusive Learning Media at SDN 2 Bengkala

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Abstrak

Penelitian ini mengembangkan SMART-AR: Buku Pop-Up Cerdas Multimodal berbasis Augmented Reality dengan fitur Braille dan Voice Over sebagai media pembelajaran inklusif di SDN 2 Bengkala. Sekolah ini menghadapi tantangan dalam pendidikan inklusif, terutama keterbatasan jumlah guru yang mahir dalam bahasa isyarat dan ketergantungan pada media pembelajaran konvensional yang tidak efektif bagi siswa tuna rungu. SMART-AR dirancang untuk meningkatkan pemahaman, minat, dan keterlibatan siswa melalui media interaktif yang menggabungkan buku pop-up 3D, teknologi Augmented Reality, dan dukungan Braille-voice over. Pengembangan menggunakan model ADDIE selama empat bulan, meliputi analisis kebutuhan, desain, pengembangan, pelatihan guru, implementasi, dan evaluasi. Hasil menunjukkan bahwa 85% guru menilai media ini efektif dalam meningkatkan pemahaman siswa, 80% melaporkan peningkatan minat belajar siswa, dan 78% guru merasa lebih percaya diri dan siap untuk terus menggunakan media ini. SMART-AR menawarkan solusi inovatif untuk mengatasi keterbatasan alat pembelajaran konvensional dan mendukung pendidikan inklusif yang lebih adil dan berkualitas di SDN 2 Bengkala.

Kata kunci: Pendidikan Inklusi, SMART-AR, Augmented Reality, Braille, Pop-up book

Abstract

This study developed SMART-AR: Multimodal Smart Pop-Up Book based on Augmented Reality with Braille and Voice Over features as an inclusive learning media at SDN 2 Bengkala. The school faces challenges in inclusive education, particularly the limited number of teachers proficient in sign language and the reliance on conventional learning media that are ineffective for hearing-impaired students. SMART-AR is designed to enhance student understanding, interest, and engagement through an interactive medium combining 3D pop-up books, augmented reality technology, and Braille-voice over support. The development employed the ADDIE model over four months, including needs analysis, design, development, teacher training implementation, and evaluation. Results indicate that 85% of teachers found the media effective in improving student comprehension, 80% reported increased student learning interest, and 78% of teachers felt more confident and ready to continue using the media. SMART-AR offers an innovative solution to overcome the limitations of conventional learning tools and supports more equitable and quality inclusive education at SDN 2 Bengkala.

Keywords: *Inclusive Education, SMART-AR, Augmented Reality, Braille, Pop-up book*

1. INTRODUCTION

Inclusive education is one of the important efforts to improve the quality of human resources in Indonesia. This education can be obtained through three pathways: formal, informal, and non-formal (Utari, 2023). To support this, educational institutions establish schools as places to conduct the teaching and learning process. According to the Central Statistics Agency of Buleleng Regency, the number of mixed public and private elementary schools reaches approximately 465 schools. SD Negeri 2 Bengkala is one of the schools in Buleleng Regency that implements inclusive education. Inclusive education has a teaching

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system that integrates children with special needs and regular children, where the school environment provides free access to learning to support children with special needs (Tarnoto, 2016). This is also stated in the Ministry of National Education Regulation Number 70 of 2009, which contains provisions on inclusive education for students with disabilities or special needs who have the right to equal opportunities to participate in education or learning within an educational environment together with regular students.

Bengkala Village receives special attention in implementing inclusive education, especially at SDN 2 Bengkala. The number of deaf people in Bengkala Village reaches 40 out of 2,275 inhabitants. Despite these limitations, they still require education equal to that of regular students. SDN 2 Bengkala is located in Bengkala Village, Kubutambahan District, Buleleng Regency, Bali. The partner location is approximately 16.1 km from the Ganesha University of Education Singaraja Campus. This observation was conducted in compliance with existing regulations and identified problems related to the limited number of educators teaching children with special needs as well as the use of conventional learning media at SDN 2 Bengkala.

Fig. 1. Team Observation at SDN 2 Bengkala

According to data obtained from interviews with the resource person, Mr. I Ketut Sulatra, the principal of SDN 2 Bengkala, he stated that teaching is overwhelming due to the limited number of educators, only 10 people with 1 inclusive teacher. The difficulty in teaching is because 9 students with hearing impairments are spread across various classes, which limits access to learning, special assistance, especially when students need additional help. Another challenge faced is the implementation of the same curriculum for all students, both children with special needs and regular children. This equalization of learning media certainly does not maximize the implementation of the independent curriculum for both regular students and children with special needs, which affects the learning outcomes. He also said that the lack of teachers who understand sign language is a serious problem that needs to be addressed quickly. The teaching method used by teachers at SDN 2 Bengkala is still conventional, using textbooks and blackboards written with white chalk. The conventional method means delivering learning media traditionally known as lectures, a method that has long been used as a medium of oral and written communication between educators and students in the teaching-learning process (Indra, Hayati, Daris, As'ad, & Mansyur, 2024). The shortcomings of conventional learning media in inclusive education for deaf children are strongly felt at SDN 2 Bengkala. Media that are generally text- and sound-based are difficult for deaf students to access. The lack of interactivity and flexibility is also one of the obstacles.

This study aims to provide training and guidance for teachers in developing learning media through the Smart-AR program: Smart Pop-Up Book based on augmented reality. The program is designed to assist students at SDN 2 Bengkala, including those with hearing impairments (deaf students) and regular students, to better understand the material in

accordance with the independent curriculum. The design of the Pop-Up Book integrates augmented reality technology with braille-voice over techniques, with the primary goal of improving the quality of student learning by increasing engagement, interest, and comprehension (Wijono, Alfi, & Fatih, 2024). This approach represents an innovation in inclusive education that responds to the need for capacity building among teachers in the current digital era, where educators are required to demonstrate increasingly high creativity in teaching, while adequate training support remains limited. Therefore, this interactive learning media is expected to enhance teachers' creativity and innovation in creating more effective and inclusive learning experiences.

In view of these problems, a preventive effort that can be made is the implementation of SMART-AR: Multimodal Smart Pop-Up Book Based on Augmented Reality with Braille-Voice Over as Support for Inclusive Learning Media at SDN 2 Bengkala. The Smart Pop-Up Book is a potential and attractive solution to be applied. A Pop-Up Book is a book that has a combination of images that can be erected and moved (Setiyaningrum, 2020). This book can enhance the 3D visualization of students so that they can feel as if what they see is real through the book (Umam, Bakhtiar, & Iskandar, 2019). The combination of Braille-Voice Over contains the introduction of sign language with images of hand movements and symbols that represent letters easily understood by students with special needs (Borman, Priyopradono, & Syah, 2019). With the combination of Augmented Reality, this book becomes easy to access by students both with special needs and regular because it is digital-based.

2. METHOD

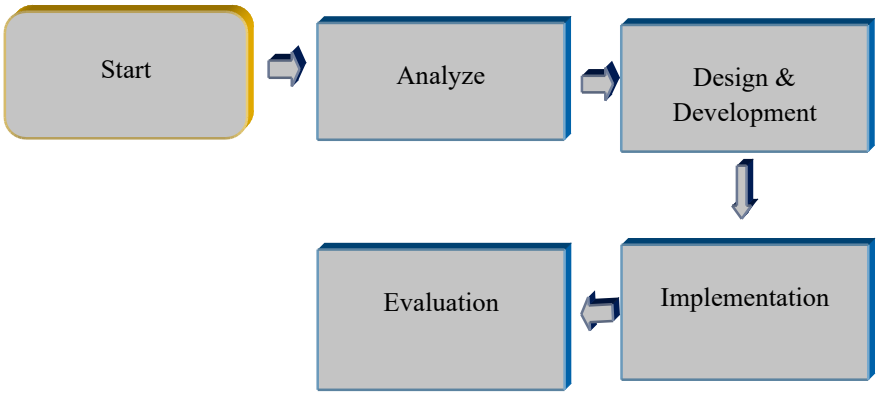

Fig. 1. Research Flow
Source: Personal Documentation

The type of research used is R&D (Research and Development). Research and Development is a method used to produce certain products with a testing process on these products. In producing a product, namely SMART-AR, which integrates pop-up books with augmented reality and voice over, research is needed to analyze the needs and test the effectiveness of the product so that it can function in the wider community, especially SD N 2 Bengkala. The subjects of this study were 10 teachers and 74 students at SDN 2 Bengkala, consisting of 9 deaf students and 65 normal students. The object of research is pop-up book learning media based on augmented reality and braille-voice over. This research uses the ADDIE development model (*Analyze, Design, Development, Implementation, Evaluation*) which was carried out for 4 months offline at SDN 2 Bengkala. At the Analysis stage, data collection was carried out through direct observation and interviews for 3 days with the principal as a resource person to identify the needs and conditions of inclusive learning. The

Design stage includes preparing a program schedule, preparing partner handbooks, consulting with learning media experts, and designing augmented reality-based Smart Pop-Up Book products using Canva and Assemblr Studio applications. The Development stage is carried out by making learning media prototypes and preparing training materials for teachers. In the implementation stage, several activities were carried out such as socializing the importance of interactive learning media, training teachers how to use applications and make learning media systematically, and providing assistance to teachers to develop and implement SMART-AR learning media to be tested on students at SD N 2 Bengkala. This trial was conducted on a limited basis to assess effectiveness, appearance and ease of use. Then the last stage is evaluation which is carried out by presenting product results, implementing media in the teaching and learning process, distributing and filling out questionnaires by partners to measure product feasibility, skill improvement, and product feasibility testing by learning media experts to obtain assessments and revisions for product improvement. The four stages are designed to ensure the feasibility of learning media to be effective, innovative and can support sustainable inclusive education at SD N 2 Bengkala. The data analysis technique uses a Likert Scale, which converts qualitative data into quantitative with the score provisions can be seen in table 1.

Table 1. Likert Scale Provision Score Table

Category	Score
Very not feasible	1
Not feasible	2
Quite feasible	3
Feasible	4
Very decent	5

In determining the average score for each aspect of the assessment, the formula is used: Mean=$\frac{\Sigma \bar{x}}{N}$, Mean=$\frac{\Sigma x}{N}$, with $\bar{x}$ = average score, $\sum x$ = total score, and N = number of respondents × number of indicators. The average results were then interpreted into the feasibility category: 5 = very feasible, 4 = feasible, 3 = quite feasible, 2 = not feasible, and 1 = very not feasible. To ensure the research data is valid, the instrument needs to be tested first using the validity test with the *product moment* correlation formula to ensure the instrument really measures in accordance with the research objectives. After data collection is complete, recapitulation and analysis is carried out using the reliability test to ensure that the data is consistent and reliable.

3. RESULTS AND DISCUSSION

SD N 2 Bengkala is still struggling to implement inclusive education effectively and enjoyably. One of the most critical challenges is the lack of teaching staff (educators) who master sign language (Ulfah & Ubaidah, 2023). At SD N 2 Bengkala there is only 1 educator who can speak sign language, causing the delivery of learning to be less efficient and deaf students have difficulty understanding the material which can exacerbate the problem. In addition, the learning process tools available are still dominated by traditional methods in the form of lectures and textbooks. These methods cannot meet the needs of deaf students who require interactive, visual and tactile teaching. The lack of interactive and educative teaching aids has a negative impact on students' contribution, motivation and academic achievement. Not only that, another crucial challenge is the lack of special needs assistants, or educators designated to provide guidance to students with special needs. This results in only some students receiving the appropriate support needed to fully understand lessons and actively participate in classroom activities. This problem highlights the urgent need for accessible and innovative learning aids. Augmented reality-based teaching aids equipped with Braille and

voice-over features provide a promising solution to this challenge and encourage the development of a more inclusive, equitable, effective and active learning environment at SDN 2 Bengkala.

The development of Smart Pop-Up Book media that integrates augmented reality (AR) technology and braille voice-over features is a major breakthrough for inclusive education. This innovation can overcome the challenges of media and learning resources that still use conventional methods that are not fully designed for all students, especially for students with sensory impairments. This media collaborates the physical and digital worlds by integrating three-dimensional (3D) pop up books with augmented reality technology that can be accessed through mobile phones, tablets, laptops, and smartphones, making it easier for students to obtain information through visual animation and interactive audio. The main advantage of this media is the ability to deliver content multimodally through 3D images, text, sound and Braille. This will certainly provide a more comprehensive and inclusive learning experience, especially for students with hearing impairments (Septiyaningtyas, Premana, & Irawan, 2024). The animated visualization of material through AR technology captures students' attention and facilitates their understanding of abstract concepts that are difficult to explain using only text or speech. The visual design can be seen in Figure 2.

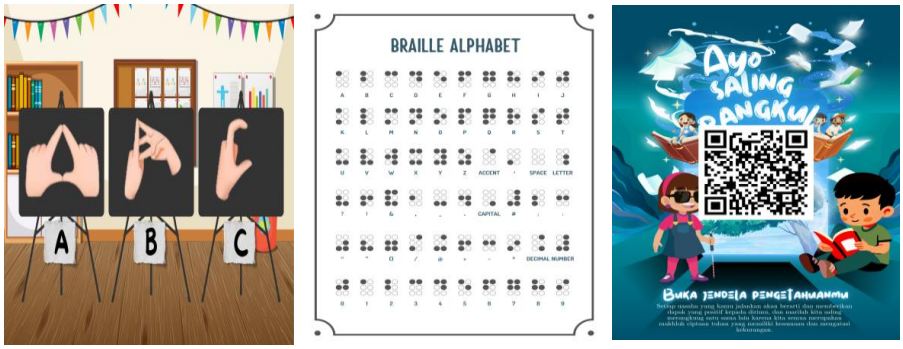

Fig. 2. SMART-AR Design
Source: Personal Documentation

Table 1. Teacher Perceptions of Smart Pop-Up Book Media Impact

Assessed Aspect	Percentage of Teachers (%)	Description
Media helps student understanding	85	Media matches the characteristics of the digital generation
Media increases student learning interest	80	Students are more engaged and active
Media matches the characteristics of the digital generation	82	Suitable for the current needs of students

Based on the analysis of questionnaires given to teachers, data show that 85% of respondents stated this media is very effective in improving students' understanding of the lesson material. Moreover, 80% of teachers noted a significant increase in students' learning interest when this media was used in the classroom. This indicates that the use of technology-based media can create a more engaging and interactive learning environment. Additionally, 82% of teachers acknowledged that the characteristics of this media are highly relevant to today's generation of students who are accustomed to interacting with digital and visual technology. Morever, this media opens opportunities for differentiated instruction, where teachers can tailor their teaching approaches according to individual student needs, including learning styles and disabilities. In other words, the multimodal Smart Pop-Up Book media

not only contributes to improving the overall quality of learning but also serves as a bridge to reduce educational access gaps faced by students with special needs. The presence of this media is clear evidence that technology can be leveraged to support more equitable, inclusive, and diversity-oriented education.

Table 2. Teacher Perceptions of Smart Pop-Up Book Media Impact

Assessed Aspect	Percentage of Teachers (%)	Description
Increase in teacher creativity	80	After training and mentoring
Increase in teacher confidence	78	In using digital media
Readiness to continue using the media	78	Support for program sustainability

Based on the data in the table above, the training and mentoring program has positively contributed to improving teachers' competence in using the Smart Pop-Up Book. From the questionnaire results, 80% of teachers think that the SMART-AR product can increase creativity and confidence in designing innovative and interactive digital-based learning media. Educators who previously only used conventional-based learning media are now able to utilize technology as part of the learning process so as to improve the quality of inclusive learning. Around 78% of teachers also feel confident in using digital media as a tool in learning, which is certainly an important indicator in the success of technology transfer to support inclusive education. To ensure the willingness and commitment of educators, around 78% stated that they would continue to use the Smart Pop-Up Book innovation for sustainable learning in the future. This shows that the training and mentoring does not only make a positive contribution in the short term, but also has the potential to continue to be developed and provide long-term benefits for inclusive learning at SD N 2 Bengkala.

In addition, 78% of teachers felt more confident in using digital media as a teaching aid, which is an important indicator of the success of the technology transfer program to support inclusive education. Interestingly, the same number of teachers, 78%, also expressed their willingness and commitment to continue using the Smart Pop-Up Book in the future. This shows that this training and mentoring program not only provides positive results in the short term, but also has the potential to continue to grow and provide long-term benefits for inclusive learning at SDN 2 Bengkala. SMAR-AR innovation has a strong potential for sustainability, with support from the school and teachers who have been trained and are able to continue training and developing similar learning media. The presence of this program can open opportunities for SD N 2 Bengkala to continue to develop into an inclusive school that is responsive to the rapid development of technology by considering the needs of students so that it can help minimize educational disparities, especially for students with special needs (deaf).

4. CONCLUSION

SD N 2 Bengkala is still facing major challenges in implementing inclusive education. This is due to several factors, namely the limited number of teachers who are able to use sign language, the lack of interactive and innovative learning media, and the lack of special assistants for students with hearing impairments (deaf). To overcome these problems, an innovation called Smart Pop-Up Book based on Augmented Reality (AR) technology equipped with Braille and Voice-over features was developed. This innovation presents media that contains multimodal content including text, 3D images, Braille, and audio so that students who have sensory barriers can more easily access information and according to the

needs of learners. Based on the results of the questionnaire, 85% of teachers rated SMART-AR media as very effective in helping students' understanding of learning and 80% of teachers felt that the training and mentoring program for using this media helped increase teacher creativity in utilizing technology in education. Overall, the Smart Pop-Up Book has great potential in supporting the sustainability of inclusive education at SD N 2 Bengkala. This innovation becomes more tangible in creating learning spaces that involve interactive, innovative, equitable learning experiences, as well as being able to bridge the gap in access to education for students with special needs. This proves that technology can be effectively utilized as a catalyst for quality, equal and future-ready education for every learner.

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