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Developing mobile augmented reality in picture book for teaching English for young learners

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Abstract: An effective language and learning process must contain interactive, fun, challenging, motivating aspects and provide more space for students to develop their creativity and independence, according to students' talents and interests; thus, appropriate teaching media can be as assisting tools. When selecting media, you need to consider several things, namely learning objectives, effectiveness, easy to obtain, students, use, not rigid, cost, and quality. One of the developments in learning media that is currently still new is learning media using Augmented Reality. This research aims to develop Augmented Reality-based text book learning media for English language learning. Developing text-book media using an application with a barcode scanner on text-books. This application displays 4D images or animations that have sound and movement so that it will help students to understand English texts. The research method used is the research and development method (Research & Development) while the product development model used is the ADDIE model (Analysis, Design, Development, Implementation, & evaluation. After developemnt anf evalution phase, the findings reveals that the outcome of teaching material product is deemed highly valid and appropriate for teaching English to yong learners, especially for primary school in this research context, as it was supported by the result of validation phase with media experts, subject matter experts, and student trials. Additionally, reflecting on the result of this study, the pedagogical implications of this result discussed further in this research.

Keywords: MAR; picture book; primary school

1. Introduction

Technology provides opportunities to improve language learning practices, especially in English learning. This can also provide solutions to some of the problems that accompany learning and teaching foreign languages, especially in learning English. By using cell phones and applications therein, teachers and students can access various educational technologies easily, as it is widely known as Mobile-Assisted Language Learning (Metruk, 2024; Sherine et al., 2020; Son, 2018). The proliferation of such mobile devices has made delivery, creation, and sharing of instructional content easier (Syamsiar, 2022). Mobile technology also facilitates learning English in an authentic, socially connected, contextually sensitive and personally accessible manner so that English learning will take place more effectively and efficiently (Rafiq & Hashim, 2018). Currently, augmented reality (AR) has become a popular tool for language learning due to the emerging innovation in technology (Banerjee, 2023; Cai et al., 2022; Yousif & Noman, 2023). The implementations of augmented reality (AR) have been highlighted in literature within different contexts in facilitating learning English as a foreign language (EFL).

This research focuses on Mobile Augmented Reality (MAR)-based picture book media as one of the latest and promising technological innovations that need further attention. MAR is an interactive experience of a real-world environment in which real-world objects are "augmented" by technology-generated perceptions, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory (Adam-Guillermin et al., 2017; Jalaluddin et al., 2020; Sabry, 2019). MAR also is a term used when the equipment used to achieve AR is small and usually easy to carry, namely like a smartphone or tablet (Koutromanos et al., 2023). In using an MAR-based Text Book, students will interact with virtual objects as if the objects were actually visible in front of them. They can find some specific information related to the object itself by using a tablet or cell phone. 3D objects come to life if they take a photo of the virtual object. For example, in text books there are barcodes that can be scanned with certain applications, then 3D/4D objects will appear on students' cell phones. The 3D/4D objects that appear correspond to the content of the material in the text book. So, this will make it easier for students to understand the content of the text, as well as help students to pronounce sentences or words correctly.

Based on a preliminary study carried out in March 2023, through a questionnaire distributed to 13 students, showed that 95.50% stated that primary students need innovative media in learning English. They are interested in audio-visual technology. Based on that, MAR media in learning English is very important and needed. In this activity, students not only read the printed media but also watched and listened to the 3D objects that appeared from the MAR application itself. The design of the MAR media is expected to meet the students' need. A study by Manna (2023) highlighted that the use of MAR in language classroom might provide some benefits such as the enhancement of learning motivation, the improvement of learning outcomes and the stimulation of more autonomous learning.

The primary focus of MAR learning-based systems is on games and simulations, utilizing the capabilities of mobile devices that possess attributes such as portability, social interaction, connectivity, context sensitivity, and individuality. However, this technology offers a wide range of possible applications and advantages, particularly in educational settings (Manna, 2023; Nincarean et al., 2013). Based on some previous research stated that students liked mobile devices' ease of use, ease of finding current information, and ease of portability as learning tools (Nincarean et al., 2013; Pombo & Marques, 2019; Setiawan et al., 2021). This research conducted a Mobile Augmented Reality with educational game. Students admitted that there were challenges in using mobile devices for learning, including the requirement for an internet connection, the speed of the connection, the fact that students are not permitted to use mobile devices in classrooms, and the fact that they provide access to distractions. In addition, MAR provides meaningful language learning (Hoang & Nguyen, 2019; Madanipour & Cohrssen, 2020; Manna, 2023). For example, a research conducted by Hoang and Nguyen (2019) in Vietnamese students. Students reported feeling more in control of their behaviour and accountable for their own education. Even though students had trouble using the app at first, they eventually mastered it and were able to work on their assignments at home or outside of the classroom. Then, MAR in the implementation of English learning was able to increase student motivation (Jalaluddin et al., 2021; Kirikkaya & Başgül, 2019; Sadikin & Martyani, 2020). AR also improves learners' target language skills Apart from that, AR plays a big role in improving English language skills, especially in daily conversation and communication. In contrast, the research findings from (Zhang et al., 2023), one of the technology acceptance investigations found that the perceived ease of use (PEOU) has no effect. One of the important factors is that the teacher should have the skills to operate and use the technology itself, especially MAR.

The advantage of 'printed AR' is its ability to change the classroom by combining textbook-based, 'pen and paper' learning with digital learning in its various forms (Majid

& Salam, 2021). Apart from that, AR-based books can increase motivation in learning (Bacca et al., 2018; Kholifah & Fudhla, 2023; Safar et al., 2017). Motivation is something that needs to be present when learning is taking place, because with motivation the class atmosphere will become more lively (Alshenqeeti, 2018). This means that in this research the textbooks developed through this research can be used because they meet the appropriateness standards according to experts, are responded to comprehensively by both teachers and students, and are effective in increasing student activity and learning achievement in elementary schools. Based on the findings and evidence above, this research recommends that teachers and parents facilitate children with AR-based textbooks as a learning medium. Then, this application is effective in helping students improve their English skills, approved by 76% of parents. AR applications are also approved by 59% of parents because they are easy to use. The AR application is proven to make it easy for students to learn English vocabulary interactively and is suitable for use as a learning medium.

To sum up, based on those previous researches and the preliminary study, the researchers conclude it is important to develop MAR picture book based on primary students' context as an innovative tool to enhance the students' capability in English since further research related to the use of AR in primary school is still underexplored. In addition, the main aim of media innovation is to improve the students' motivation, contribution, and engagement in learning English. Thus, the purpose of this study includes twofold objectives including developing MAR picture book for primary school students and evaluating its effectiveness using ADDIE (Analysis, Design, Development, Implementation dan Evaluation) approach. This research might contribute to the body knowledge and give pedagogical implications for teachers, EYL practitioners and school partners in associated with the use digital teaching media to teach English to Young Learners (henceforth EYL).

2. Materials and Methods

2.1 Types of research

This research is Development Research or Research and Development (R&D). Research and development is a process or steps to develop a new product or improve an existing product, which can be accounted for (Dewi et al., 2021). Research and development methods are research methods used to produce a particular product and test the effectiveness of the product (Basturkmen, 2010). This research aims to develop a product in the form of a textbook media based on Augmented Reality (AR) for English language learning. The media is developed according to the needs of students, materials, and abilities of lecturers and students. Based on a preliminary study carried out in March 2023, students need learning media that is integrated with developments in digital technology. Referring to the results of the preliminary study, researchers developed Augmented Reality (AR)-based textbook media using the ADDIE method to test media suitability and others. This research procedure applies the ADDIE development model (Figure 1). ADDIE stands for Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009).

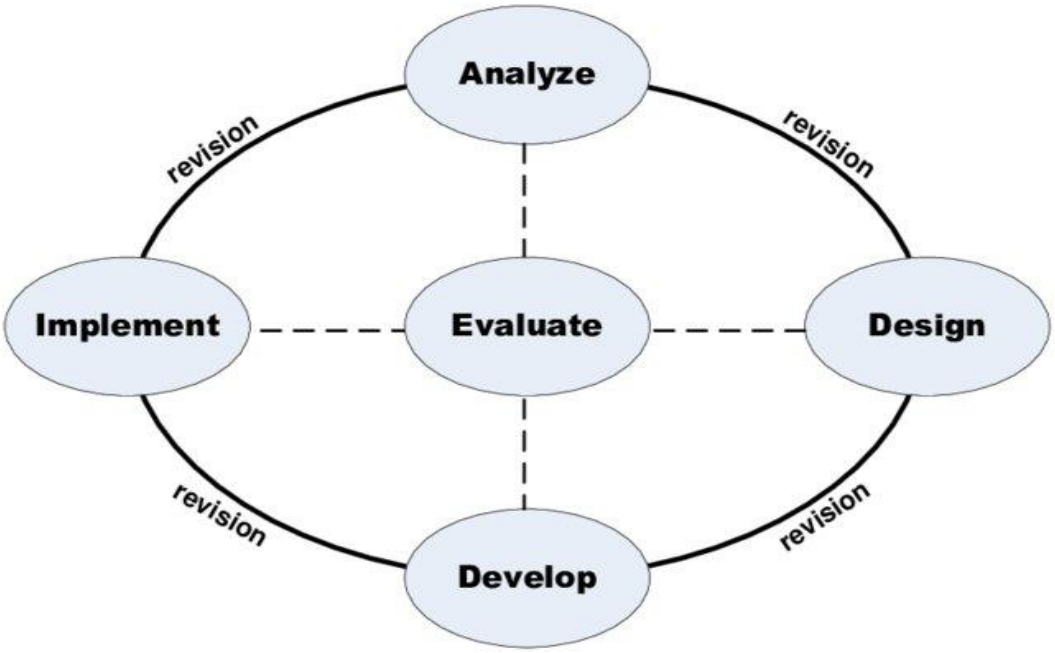

Figure 1. ADDIE's Chart

According to Branc, the main goal of the analysis stage is to identify possible causes of disability at work. In this case, he pointed out whether the performance gap is caused by a lack of knowledge and skills, then suggested training options and developing a statement of intent. Besides the analysis stage, this is the data collection stage for learning design (Mesra, 2023). Every instructional designer collects all the information they can gather about the course before they consider things other. Additionally, the instructional designer clarified problems to be addressed with intervention instructional, defining training needs and conducting a broad audience analysis to determine the instructional environment, existing knowledge, skills and abilities, opportunities and constraints.

2.2 Research Subjects and Objects

This research was conducted at the ABA VII Babat Kindergarten pre-school in April - May 2024, because the target of this research is English for Young Learners (EYL) or students at the pre-school level. Meanwhile, the subjects of this research used validation techniques triangulation, namely by involving a content/learning material expert, an expert learning media, colleagues/teachers who implement the MAR in class, and 13 students. The students consist of 8 Females and 5 male students. They are in primary level around 6-7 years old. They came from different backgrounds of family. The teacher said that eight of them could read a text fluently.

2.3 Data Types and Sources

The types of data used in this research are primary data and secondary data. Primary data consists of the validation of MAR development itself such as the process of developing MAR in a picture book, creating the picture book, the validation of the experts, and the implementation in the class. The secondary data was obtained from interviews and observation. Which is looking for the obstacles or challenges faced by the teacher and students in implementing MAR itself. This research uses the ADDIE model. The ADDIE model stands for Analysis, Design, Develop, Implement, and Evaluate which was developed by Reiser and Mellenda. ADDIE is a learning/training design model that is generic and serves as a guide in building training program tools and infrastructure (Wong & Looi, 2011). It is effective, dynamic and supports English language teaching at the primary level the results of interviews with school community data sources consisting of

the principal, deputy curriculum 4 subject teachers, secondary data obtained from documentation studies of learning plans (teaching modules) and assessment data.

2.4 Data collection technique

One of the most crucial phases of research is the data collection phase. Proper methods of gathering data will yield highly credible data, and vice versa. Therefore, it serves as a foundation for research to gather the data required to create a learning application. It employs the following four techniques for gathering data. Verbal primary data were collected directly from informants in the form of teachers and students at TK ABA Babat through interviews. Secondary data in the form of books or comments regarding teacher data and competencies and collecting the data needed in this research, by reading and searching from several books, research reports, and previous scientific articles related to interactive learning media, from basic aspects of computer introduction material using models ADDIE.

The process of observation involves monitoring or detecting issues that arise in students related to a lack of learning resources. Based on these observations, an analysis was conducted to determine the research problem and provide a foundation for future research and learning media creation. Following a series of questions that students (respondents) were asked to complete, the following data phases were obtained using a survey that asked respondents to complete a Google Form and provide answers to a number of questions.

2.5 Data Analysis Techniques Data Analysis Techniques

This model was chosen because it is often used to describe a systematic approach in developing instructional media. In addition, this model is general and suitable for use in development research. This term is almost synonymous with instructional system development (Mafruudloh et al., 2022). When used in development, this process is considered sequential but also interactive, where the evaluation results of each stage can bring learning development to the previous stage. The final result of one stage is the initial product for the next stage. The development stages in this research are as follows.

1. Conduct a needs analysis by conducting a preliminary study related to students' interest in implementing Augmented Reality-based text-book media.
2. Determine the objectives of developing Augmented Reality-based text-book media, adapting to English language learning needs.
3. Develop media according to English learning needs so that it is easy to use by students and teachers.
4. Implementing text-book media based on MAR in English learning, especially at primary school level.
5. Conduct evaluations related to planning, development, implementation and media feasibility.

The subjects of this research are students, material experts, and media validation experts. The techniques used in analyzing data are as in the Table 1.

Table 1. The eligibility score category

Score	Category
4	Excellent
3	Acceptable
2	Below average
1	Unacceptable

To calculate the average score on each aspect, the researchers used Microsoft excel calculation. Meanwhile, to interpret qualitatively, the average number of scores for each

aspect were grouped based on several criteria. The Table 2 is a reference for score conversion criteria.

Table 2. Score conversion criteria

Score	Category
4	Excellent
>2.5-3.25	Acceptable
>1.75-2.5	Below Average
1.0-1.75	Unacceptable

In addition, to know the classification of students' response, the researcher used in %. The classification in the Table 3.

Table 3. The classification of students' response

%	Category
81.25-100	Excellent
62.49-81.24	Acceptable
43.73-64.48	Below Average
25-43.72	Unacceptable

3. Results

3.1 Implementation of the Project-Based Learning Model

This research product is MAR picture book-based. The picture book contains two languages, Bahasa Indonesia and English. The book contains illustrated stories. The users need a MAR application named "Hello Aisyah" to scan the picture as a marker. It is implemented in Primary school context or English for Young Learners (EYL) to enhance their motivation and participation in Learning English.

3.1.1 Analysis

In our previous need analysis, the teacher needs innovative media related to technology in teaching English. Based on the previous interview, the teacher used conventional media such as whiteboard, LCD, and paper-based. Then during the COVID-19 pandemic, students used technology-based media, such as video conferences using their parents' smartphones. It became a habit, integrating technology into language learning. Then after that, the teacher still used conventional aids while teaching in a face-to-face setting. The students got bored. They have no motivation and low participation in learning English. They also got low scores in English. They need innovative media integrated with the technology. There was an analysis of students' characteristics, students' needs, and learning facilities/sources.

First was the students' characteristics. The subject was 13 students who came from different backgrounds of family. Some of them are familiar with the usage of technology, and some of them are not. They also belong to the kinesthetic learner, because they move along the teaching process. Then, based on the interview with the parents. The students need attractive media, because so far students get conventional teaching such as doing the assignment in LKS, drilling, and memorizing the vocabulary. Whereas the school has proper facilities to integrate the technology in teaching EYL.

3.1.2 Design

This stage includes several activities, including developing materials instructional by the Minister of Education, Culture, Research and Technology Regulation number 22 of 2022 concerning book preparation standards; and the development of Mobile augmented reality (MAR) "*Hello Aisyah*". Results at this stage of development include a teaching material product in the form of a MAR-based picture book that has been structured

accordingly with applicable competencies as well as questionnaires to measure validity and research subject responses (Figure 2).

Figure 2. The MAR app process

In the functional model, the software explains the overview of the software Starting from the creation of 3-dimensional objects, sound file creation, search, and image formation so that it becomes a marker library, combined into one augmented reality project AR (augmented reality) library and coding process is a major component of software development augmented reality (Figure 3).

Figure 3. Software architecture design

3.1.3 Development

At this stage, there were three steps in developing MAR Picture Book "Hello Aisyah", such as making story storyboard, illustrating the story, designing MAR, and developing MAR app in picture book itself. In order to make the storyboard, the writer should share the description of characters, characteristics, and what kind of situation that the story has. The story board could be seen in this link https://bit.ly/StoryBoardHelloAisyah. Then the illustration should proper with the subject or the targeted reader. The color and text also should have a proper type, this book used CMYK color. Just like RGB, CMYK is an abbreviation of Cyan, Magenta, Yellow, and Key (Black). These colors will be combined into new colors. In fact, by combining cyan, magenta and yellow could create black, but the resulting black is not jet black. So, black was added to complete this color model. CMYK is often used in the printing industry, both images and writing (Figure 4).

Figure 4. The picture book in Bahasa Indonesia Version

The picture book is a series of story. It told the reader about family, religion, sibling, friendship, and value of life. It based on the governor regulation, Book leveling guidelines from the Ministry of Research and Technology of Indonesia. The readers subject is for beginner readers covering A (0-7 years old), B-1 (6-8 years old), and B-2 (7-9 years old). In Indonesia, especially East Java those children belong to Primary schools' students, consisting Kindergarten and elementary school. The book also belongs to the wordless book, because it only shared short sentence. The writer emphasizes on the illustration itself to deliver the message (Figure 5).

Figure 5. Application MAR on Android "Hello Aisyah!"

The application of MAR is for Android. The users could download the link from https://bit.ly/AppHelloAisyah. After downloading the users could scan the marker or picture. After that, the 3D picture and the English version text appear (Figure 6). In addition, the users could listen to the pronunciation and musical instruments from the application. The pronunciation/ sound aimed to guide the user to pronounce well.

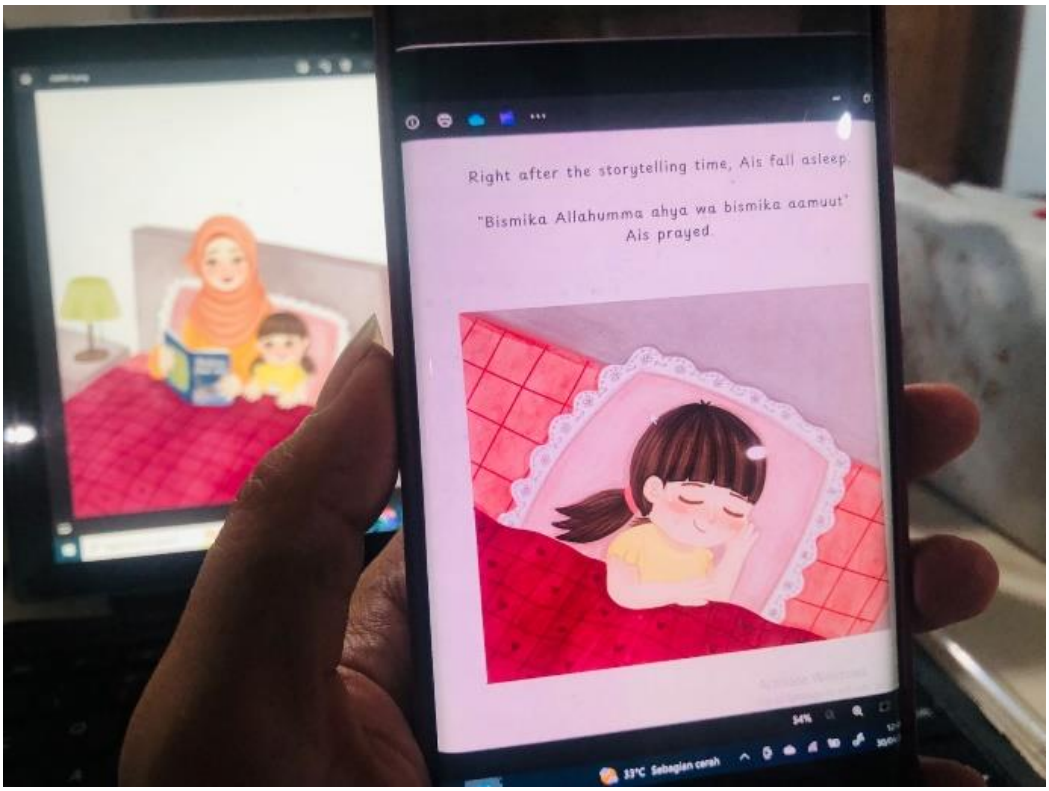

Figure 6. The English version in MAR

3.1.4 Implementation

This research was conducted in the B grade of TK Aisyiah Bustanul Atfal (ABA) V Babat. They were 13 students with different background of family, teacher, and two validators of teaching material and media. In the first meeting, the teacher gave an introductory session. She told the students about family members in English. The teacher drilled the vocab related to family, invited them to sing together, and having physical activity such as run, jump, etc. After that, the teacher invited them to listen the story. In this situation, the teacher done the story telling in front of them. Next meeting, the teacher invited them to use smartphone. The students attracted and motivated in reading by using MAR. They also repeating the pronunciation together guided by the teacher. In the last meeting, teacher invited them to do the evaluation. Before giving the evaluation, the teacher retelling the story and the characters. The aim of evaluation was to check the students' comprehension in reading. It also assessed their vocabulary related to the material.

3.1.5 Evaluation

The evaluation covers the validation score from both material and media experts, the student's response, and the teacher's response. The data was obtained from the questionnaire and calculated statistically.

a. Material and content

The statements consist of 13 questions. Those represent material, language, and evaluation. The material covers the presentation of basic competence (for reader level A-B2), the relevance between basic competence and the material, the relevance between the material and the student's characteristics, and the delivery of the material itself. The average score of the material aspect was 3.5, which means excellent or very acceptable (Table 4).

Table 4. Material/content validation score

Aspect	Score	Classification
Material	3.5	Excellent
Language	3	Acceptable
Evaluation	4	Excellent

Based on the table above, the language aspect was 3 which means acceptable. These aspects cover the display, communicative language used, harmony and coherence, students' stage development, and material completeness. The evaluation aspect covers the way of knowing the readers' comprehension. In MAR picture book itself contains 3 pages of the evaluation. This aspect got 4, which means excellent or very acceptable.

b. Media of MAR

Media means the application of MAR in picture books. The data also was obtained from the questionnaire. It contains 15 statements that represent display, materials' relevance, and instruction. In display aspect involves size, color, symbol, frame, and the ease of reading. It got 4 which means excellent or very acceptable. The validator commented that the application is simple and easy to use. There is no complicated menu or instructions. The user could enter the display directly. Next, the material's relevance covers linkages between the illustration displayed and the material. This aspect also got an excellent score of 3.4. Lastly, instruction involves ease of operation, link accuracy, media flexibility, and instruction clarity. This aspect got 3.3 (Table 5).

Table 5. Media validation score

Aspect	Score	Classification
Display	4	Excellent
Material's relevance	3.4	Excellent
Instruction	3.3	Excellent

c. Students' response

The students' response data was obtained from the guided questionnaire. The teacher guided the students and they answered orally because they could not read fluently yet. The questionnaire consists of ten questions. It found that 5 questions were acceptable and 5 questions were excellent. 80.76% of students feel happy using MAR because it contains interesting pictures and sound (Table 6).

Table 6. Students' response

Statements	Score in %	Classification
Students feel happy in using interactive learning because it contains clear material and interesting augmented reality learning media	80.76923	Acceptable
Students feel more interested in learning English using augmented reality because it contains clear and interesting material	84.61538	Excellent
Students can concentrate because the media contains clear illustrations	71.79487	Acceptable
Students increase their knowledge of English in learning by using MAR	79.48718	Acceptable
Students are more motivated because they can learn English vocabulary using MAR	84.61538	Excellent
Students get a better understanding	89.74359	Excellent
students become enthusiastic in learning participation.	82.05128	Excellent
English learning becomes easier by using the MAR	71.79487	Acceptable
MAR attracts the students' interest in learning English	82.05128	Excellent
Students support the use of interactive learning media using MAR	71.79487	Acceptable

Table 6 shows that 84.61% of students also increased their concentration because the media contained clear illustrations, 84.61% increased their vocabulary and 79.48% increased their knowledge of English. It was also proved by the teacher's statement that students could memorize new vocabulary from the book. 89.74 % showed better understanding in learning English, it proved by their enthusiasm in discussing, answering, and doing the exercise in the book itself. Overall, 82.05% of students are interested in learning English and 71.79% support using the MAR book as their media in learning English.

Implementing MAR in EYL also gives benefits, especially in learning English. Data in Table 7 was obtained from the interview with the teacher and students.

Table 7. Students' opinions related to MAR

Opinion	f
Increase motivation	13
Vocabulary acquisition	7
Engage participation	8
Understandable topic	9
Interesting illustration	12

4. Discussion

This development research produced a MAR-based picture storybook for level A-B2 readers. This product is categorized as very valid and suitable for use after fulfilling the validation stage of material experts, experts in media, and trials with students. Based on the data obtained, there were some challenges in developing this media. First is effective

in computing When the personality and collaborative compute outsourced Web AR implementation choices are taken into account, the computation and rendering capabilities of mobile platforms become even more significant in augmenting the functionality of Web AR applications (Huang & Bin Hamdan, 2023; Kurkovsky, 2012).

Second, In the long run, augmented reality applications require interaction perception, environment monitoring, and an active Internet connection. All of these power-intensive tasks seriously shorten the battery life of portable electronics. However, the battery can only be utilized for necessary operations at this time. It was also proved by previous research by Banerjee (2023), that energy efficiency must be taken into account because web augmented reality apps may negatively impact mobile devices. Third is knowing students' characteristics. In this situation, young learners are well-positioned to solve problems because of their natural curiosity about the world, risk-taking attitude, and capacity for quick learning from mistakes. When it comes to connecting and interacting with classmates both inside and outside of the classroom, elementary school children thrive on activities that cater to their needs for both peer collaboration and peer competition (Agata et al., 2021; Benlaghrissi & Ouahidi, 2024).

They are also able to recognize problems, are motivated to find answers, and are open to change. In developing media, it is important to know students' characteristics. It will be a fit and proper media to support their learning process. Last is the learning goal. Learning objectives are also one of the crucial considerations in making learning media. The relevance of the chosen medium is meant to be appropriate for the demands of the educational setting. That means that the goal of employing any kind of media is based on the needs of the students (Hikmah, 2019; Lee Juhee, 2021; Mat Sa'ud et al., 2023). Picture book created for A-B2 readers. The story is also understandable and eye-catching. The media also provided interesting illustrations related to the story. Based on those challenges, researchers recommend that in making media, especially for young learners, the media maker should know the students' characteristics, learning objectives, and school devices. If those things are fulfilled, the media implementation will be effective and helpful.

Implementing MAR in EYL also gives benefits, especially in learning English. This data was obtained from the interview with the teacher and students. First, MAR increased the students' motivation to learn English. With capabilities that traditional learning media do not have, augmented reality technology is an engaging media. Additionally, using augmented reality (AR) on smartphones is thought to attract students (Karagozlu & Ozdamli, 2017; Nghi & Thang, 2024). One is more motivated to study more when they are engaged in a subject. Students will undoubtedly retain their knowledge longer if they are more motivated to learn. Additionally, it is envisaged that this will raise pupils' academic performance. Overall, the result of this research congruent to the previous studies conducted by Megawati et al (2023), Yang and Zhang (2024) along with Liao et al (2024), affirming that AR holds great promise in enlivening and enriching English language lessons.

MAR also Enriched students' vocabulary. It takes understanding form, meaning, and usage to increase one's vocabulary. Stated differently, a young learner needs to be able to recognize a word's spelling, pronounce it, understand its meaning, and know when and how to use it. Given their immature cognitive capacities, this can be extremely difficult for young, sluggish learners. Moreover, young learners may not be able to immediately understand the many abstract notions included in the English language. It is in line with the previous study by Jalaluddin et al., (2021), study shows that MAR helps students become more motivated and engaged, which ultimately results in higher performance scores, and successful vocabulary levels. This shows that students with special needs can benefit from technology; however, further in-depth research is needed to determine the readiness and willingness of students and teachers to use mobile applications for teaching.

The availability of MAR-based learning resources presents an opportunity for the country's youth to act as change agents and raise the bar for instruction based on renewable technology in Indonesia. However, the scope of this research is limited to the validity and usefulness of the test phases for instructors and students; subsequent studies will assess the test's efficacy and the overall mechanics curriculum. This study has implications for raising student interest and motivation in using digital technology in the classroom due to the demands of the curriculum developed by the Institution. The curriculum is practical, flexible, interactive, and aligned with the competency requirements of 21st-century skills.

Although this research conveys some limitation, the findings of this research serve significant pedagogical implications for teaching English to Young Leaners. First, to provide an appropriate teaching and learning activities in class, a need analysis preceding to teaching material development was crucial to be conducted. Thus, the content of the designed learning materials merits to the students' needs. Second, using MAR technologies, especially in teaching English to young leaners is highly suggested as it is proven to enhance students' interest and motivation to learn English. English teachers, and EYL practitioners are urged to develop more Mobile-Assisted Language Learning (MALL) applications to improve the outcomes of the learning process. All in all, the result of this study might be a fundamental prior study for further researchers to conduct more research in related to the use of digital teaching media to provide contextualized teaching media for young learners in various Indonesian EFL settings.

5. Conclusion

The study's findings provide compelling evidence for the pedagogical benefits of MAR-enhanced learning applications for instructional design and learning procedures. At the same time, it highlights major obstacles to the use of MAR technologies in education, which, in the case of the pilot project under consideration, mostly relate to faulty software. The aforementioned research findings make it clear that more work needs to be done in the areas of teacher preparation, educational practice in schools, and MAR-enhanced learning applications to guarantee that every student can fully benefit from the wealth of opportunities that AR technologies present for teaching and learning.

Authors Contribution: N. M.: methodology, conducting the research and writing original article, and field data collection. F. A.: Developing the MAR application and data analysis. K. K.: data analysis, writing original article and revision.

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