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Development of a Problem-Based Learning Model Integrated with Assemblr Edu Augmented Reality Based on the SAMR Model in Elementary School Multiliteracy Learning

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ABSTRACT

The goal of this project is to enhance primary school multiliteracy education by developing a Problem-Based Learning (PBL) model that incorporates Assemblr Edu Augmented Reality (AR) according to the SAMR framework (Substitution, Augmentation, Modification, and Redefinition). This research followed an R&D process outlined by Lee and Owens, which consists of the following steps: analysis, design, development, implementation, and assessment. To address this limitation, the present study proposes the integration of Augmented Reality in multiliteracy learning to bridges the gap between theory and practice by demonstrating that technology has the potential to alter the way in which children learn rather than just replacing it. Involvement, critical thinking, and the numerous literacy skills necessary for success in the modern digital world are all aided by this for elementary school children. This demonstrated the need for a technologically-based, interactive solution. The study involved 128 elementary school students from two schools, while the effectiveness test was conducted with 35 students using a one-group pretest-posttest design. Professionals in both the material and media fields thought the product was excellent (86.67% for the former and 81.25% for the latter). Results from the practicality tests showed that students (97.14%) and teachers (91.67%) found the strategy to be very applicable.

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An improvement in multiliteracy skills was shown by the effectiveness test, which used a one-group pretest-posttest design. Average scores increased from 69.43 to 93.23. The findings show that the AR-integrated PBL strategy is realistic, feasible, and effective in improving student involvement, comprehension, and creativity.

Keywords: Augmented Reality (AR), multiliteracy learning, problem-based learning

INTRODUCTION

The rapid advancement of digital technology has significantly influenced contemporary educational practices, transforming the way teachers organise learning, and how students interact with knowledge. Modern classrooms increasingly incorporate digital platforms and interactive technologies to create learning environments that are more engaging, collaborative, and student-centred. One pedagogical strategy that aligns with these developments is Problem-Based Learning (PBL), which encourages students to explore authentic problems and construct knowledge through inquiry and collaboration (Setiawan et al., 2024). By presenting real-world scenarios, PBL supports active learning and accommodates diverse learning preferences, enabling students to participate more meaningfully in the learning process.

Among emerging educational technologies, AR enables students to interact with digital objects while remaining connected to their physical learning context, which can support visualisation and conceptual understanding. (Nygård et al, 2021; Wiraha & Sudarma, 2023). Studies have suggested that AR-based learning environments can enrich traditional classroom instruction and create immersive learning experiences that stimulate curiosity and engagement (Carrión-Robles et al., 2023; Cahyana et al., 2023; Guo & Kim, 2022). Platforms such as Assemblr Edu provide educators with tools to develop interactive AR learning materials that can attract students with varying reading abilities and learning interests (Messadi et al., 2018; Petrov & Atanasova, 2020). In addition, digital technologies have shown promising potential in supporting literacy-related learning activities, particularly in reading and writing instruction.

The concept of multiliteracy has become increasingly important in contemporary educational discourse (Ang & Tan, 2020; Lim et al., 2022). Several studies have demonstrated that the use of digital learning tools within multiliteracy frameworks can improve students' motivation, writing ability, and creative literacy development (Azizah & Triastuti, 2024; Fudhaily & Rahman, 2022). Ganapathy and Seetharam (2016), and Lestari et al. (2024) stated that multiliteracy refers to the ability to interpret and produce meaning through multiple forms of communication, including written language, visual representation, and digital media. As communication practices evolve in the digital era, students are expected to develop competencies that extend beyond traditional literacy skills (Dewi et al., 2020; Hesterman, 2011; Zhang & Yan-xun, 2020). Learning environments that incorporate multiliteracy principles allow students to engage with information presented through various modes and encourage them to express ideas creatively (Pishol & Kaur, 2015; Setiawan et al., 2019). Consequently, integrating digital technologies with multiliteracy-oriented instruction is increasingly viewed as an effective strategy for preparing students to navigate complex digital communication landscapes (Burke & Hardware, 2015).

In order to integrate technology effectively into learning processes, educators often rely on conceptual frameworks that guide pedagogical decisions. One widely recognised framework for technology integration is the SAMR model, which describes four progressive levels of technology use in education: substitution, augmentation, modification, and redefinition. This model provides a conceptual structure that helps teachers understand how digital tools can enhance or transform learning activities. Through the SAMR framework, educators can evaluate whether technology merely replaces traditional practices or enables the creation of new forms of learning that were previously not possible (Dewi et al, 2023). Previous studies have highlighted that applying the SAMR model in instructional design can support more effective integration of digital technologies in classroom practice (Ghimire & Pandeya, 2020; Rahman et al., 2022). Within multiliteracy learning contexts, the SAMR framework can assist teachers in designing learning activities that encourage students to engage with multimodal texts and develop digital storytelling skills.

Despite the increasing interest in the use of AR and the effectiveness of Problem-Based Learning, many studies have examined these approaches independently rather than integrating them within a unified instructional design. Research on AR in education frequently emphasises technological affordances such as visualisation or interactivity, while studies on PBL often focus primarily on collaborative problem-solving processes. As a result, limited attention has been given to how AR technology can be integrated within structured pedagogical frameworks to support multiliteracy learning outcomes. Moreover, many theoretical discussions of multiliteracy emphasise the importance of multimodal communication but provide limited practical guidance for teachers on how to implement these principles in real classroom settings.

Another limitation of existing research is that AR applications in education are frequently concentrated in science, technology, engineering, and mathematics (STEM) disciplines. Comparatively fewer studies have explored the role of AR in literacy or multiliteracy development, particularly among elementary school students. In many cases, AR is used mainly as a visualisation tool rather than being integrated into comprehensive instructional models that support higher-order thinking skills such as problem solving, creativity, and critical thinking. Consequently, further research is needed to develop pedagogical models that combine AR technology with structured inquiry-based learning strategies such as Problem-Based Learning.

Although previous studies have explored the use of Augmented Reality in education and the implementation of Problem Based Learning to enhance students' literacy skills, most of these studies focus on the technological aspect of AR or the pedagogical effectiveness of PBL separately. Only limited research has systematically integrated AR technology within a structured technology integration framework to support multiliteracy learning. In many cases, AR is applied merely as a visualisation tool without a clear pedagogical and technological alignment. Therefore, this study proposes a structured integration of Problem Based Learning, Augmented Reality using the Assemblr Edu platform, and the SAMR framework to guide the transformation of learning activities from substitution to redefinition. This combination provides a more comprehensive instructional design that aligns pedagogy, technology, and multiliteracy learning objectives in elementary education. By positioning the SAMR model as a framework for integrating AR within the stages of Problem Based Learning, this study offers a practical model for implementing technology enhanced multiliteracy learning in elementary schools.

To address this gap, the present study proposes an instructional model that integrates Problem-Based Learning with Augmented Reality using the Assemblr Edu platform, guided by the SAMR framework as a model for technology integration. In this approach, the stages of PBL are aligned with the levels of the SAMR model to create learning activities that progressively transform the use of technology in the classroom. By integrating AR technology into problem-solving activities, students are encouraged to explore complex concepts through interactive and multimodal learning experiences. This study contributes to the growing body of research on technology-enhanced learning by proposing an instructional model that systematically integrates Problem-Based Learning, AR, and the SAMR framework within a multiliteracy learning context. While previous studies have explored the use of augmented reality or problem-based learning independently, limited research has examined how these approaches can be combined within a coherent pedagogical structure that supports multiliteracy development in elementary education. By aligning the stages of Problem-Based Learning with the levels of the SAMR framework and implementing them through the Assemblr Edu augmented reality platform, this study offers a structured approach for integrating digital technology into literacy-oriented learning activities.

The primary objective of this study is to design and evaluate a Problem-Based Learning model integrated with Augmented Reality based on the SAMR framework to support multiliteracy learning in elementary schools. Specifically, this study aims to identify multiliteracy learning needs that can be addressed through AR-supported learning environments, develop a PBL instructional model utilising the Assemblr Edu platform, evaluate the feasibility of the developed model through expert and practitioner validation, and examine its effectiveness in improving the multiliteracy skills of elementary school students. By integrating pedagogy, technology, and multiliteracy principles, this study seeks to contribute a practical instructional framework that supports more engaging and meaningful learning experiences in primary education.

LITERATURE REVIEW

Augmented Reality may be used to assess and report in regular schools with the goal of improving bilingual education. Teachers have utilised this to encourage their pupils and provide them with a secure place to study and develop. Double reality, which merges our digital and physical worlds, has the potential to reawaken our dormant aspirations of learning, writing, critical thinking, and collaboration. This study is the first of its type to experimentally investigate the potential advantages of augmented reality (AR) on traditional instructional methods. The research indicates that augmented reality's ability to facilitate interactive and exploratory learning might substantially influence student motivation, understanding, and collaboration. According to Apriza et al. (2024), augmented reality (AR) made primary school math sessions more interesting for students and helped them understand arithmetic ideas better. More student involvement is needed to connect literacy classes to other disciplines (Quintana et al., 2020).

Based on earlier research, this study suggests that augmented reality (AR) might make lessons more interesting, which would therefore make students more likely to think critically and creatively. AR improved the PBL environment by encouraging students to learn via exploration and critical thinking. Students may learn and understand things better by immersing themselves in a mix of real-world and interactive digital aspects. The time has come to be able to criticise. Zafeiropoulou et al. (2021) shows how augmented reality may be used to enhance PE. Students' theoretical knowledge and practical abilities were both enhanced when they employed enhanced augmented reality devices in their study. (Zafeiropoulou et al., 2021). The kids not only learned the material better, but this immersive learning style also made them want to work together to discover answers.

The SAMR framework (Substitution, Augmentation, Modification, and Redefinition) states that AR applications may be utilised in many different ways to help people learn. First, AR may replace traditional media that provides more engaging interactions with material that improves the learning process. From that point, AR is able to transform learning activities by adding interactive components that enable learners to visualise high-level concepts within a three-dimensional environment that offers richer insight. As learning tasks become more advanced, the potential offered by AR corresponds with the redefined interaction where learners are able to develop completely new types of content that intersperses the real with the virtual that demonstrates a transformation of delivery of the curriculum (Chen, 2019).

Although previous studies have demonstrated the potential of Augmented Reality in enhancing student engagement and visualisation in learning, many of these studies primarily focus on technological affordances rather than pedagogical integration. Similarly, research on Problem-Based Learning has shown its effectiveness in promoting critical thinking and problem-solving skills, yet only a limited number of studies have explored how emerging technologies such as Augmented Reality can be systematically integrated within the PBL framework. In addition, while multiliteracy studies emphasise the importance of interpreting information across multiple modes, practical instructional models that combine multiliteracy pedagogy with technology integration frameworks such as SAMR remain limited. Therefore, further research is needed to design an instructional model that meaningfully integrates AR technology, pedagogical strategy, and multiliteracy development in elementary education.

The written works highlight that there is value in creating AR applications that are specifically designed while accounting for the needs of individual learners as well as the educators' strategies. (Hidayat et al., 2021) also emphasise that there needs to be more exploration of the potential of AR's use within elementary education and its use specifically to develop literacy abilities as well as enhance motivation (Hidayat et al., 2021). Problem-based learning spaces facilitated by AR technology are an example of a new learning paradigm that fosters innovative abilities in students. The goal of integrating AR with PBL is to improve students' performance in high-level skills such as analysis and evaluation by giving them the opportunity to test assumptions and demonstrate understanding via experiential learning (Hoe et al., 2024; Pedaste et al., 2020). Our findings are in line with previous research that shows how modern literature demands innovative teaching practices to increase intrinsic motivation and academic performance (Booyoesen, 2023; Marrahí & Belda, 2024).

This study contributes to existing literature in several ways. First, while previous studies have examined the use of Augmented Reality in education, many of them focus primarily on visualisation or engagement aspects without integrating a comprehensive pedagogical framework. Second, research on Problem-Based Learning supported by digital technologies has rarely incorporated the SAMR model as a systematic framework for guiding the level of technology integration. Third, studies on multiliteracy learning in elementary education often emphasise literacy practices but provide limited guidance on how emerging technologies can be pedagogically embedded within instructional models. Therefore, the novelty of this study lies in the integrated design of a learning model that systematically combines Problem-Based Learning, Augmented Reality using the Assemblr Edu platform, and the SAMR framework to support multiliteracy development in elementary school contexts.

METHODOLOGY

This study employs the instructional design framework research and development articulated by Lee and Owens (2004), including analysis, design, development, implementation, and evaluation (Figure 1). The first step in development is to identify the needs of the target audience and conduct the first round of interviews by talking to and listening to them. The development technique of the PBL-AR paradigm was centred on storyboards, which included text, images, symbols, and audio. Then it was examined by specialists. Throughout the deployment phase, the product was administered to students in classrooms to gauge its usefulness according to teacher and student input, and its efficacy

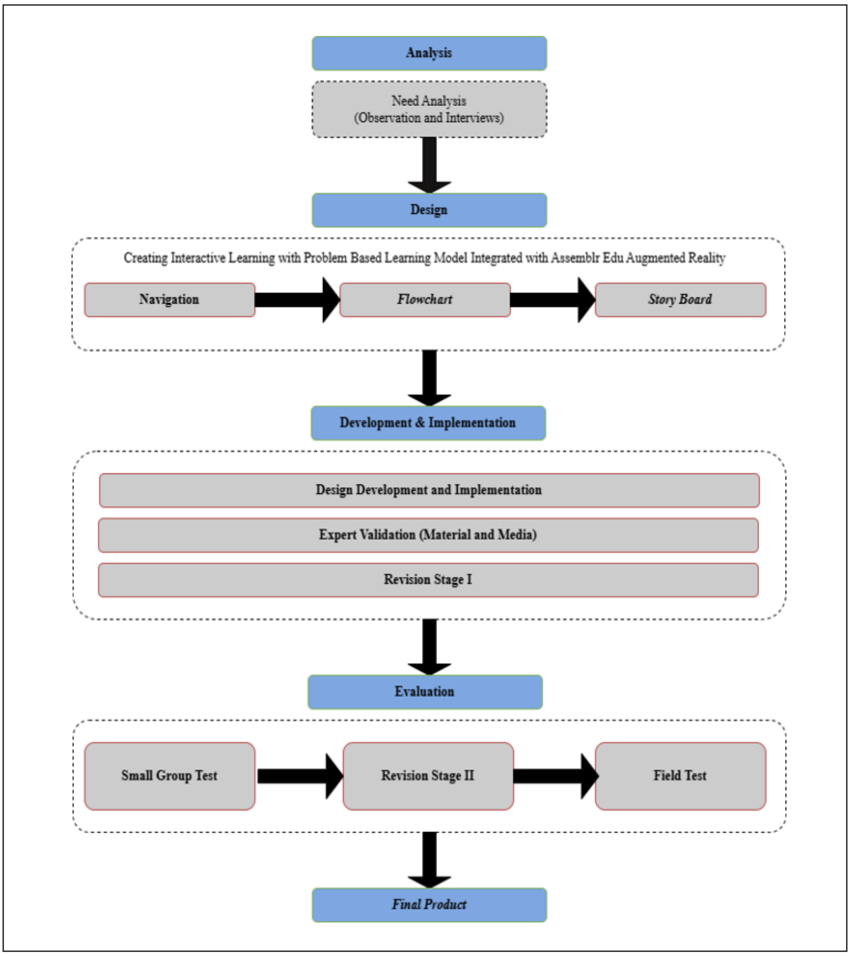

Figure 1. Lee and Owen model development stages

according to a one-group pretest-posttest design. Lastly, the product was improved throughout assessment by incorporating expert comments, validation surveys, and student learning results.

One group pretest posttest design is employed to evaluate the initial effectiveness of the developed learning model. This design was selected because the primary objective of the study was to test the feasibility and preliminary effectiveness of the developed product within the Research and Development framework. However, the authors acknowledge that the absence of a control group may limit the ability to attribute observed improvements solely to the intervention. Therefore, the results of this study should be interpreted as preliminary evidence of effectiveness. Future studies are recommended to employ a quasi-experimental design involving a control group to obtain stronger causal evidence regarding the impact of the developed learning model.

The study involved 128 students from two elementary schools: SDN Pisang Candi 2 in Malang, East Java and SDN Jomblang 1 in Semarang, Central Java. The participants were selected using purposive sampling based on the accessibility of schools that were willing to implement the developed learning model. The participants consisted of second grade students aged approximately 7-8 years. The sampling procedure was intended to represent typical elementary classroom conditions where multiliteracy learning activities are implemented.

The development process included two stages of product trials. The initial trial involved 43 second-grade students who were categorised into three ability groups (high, medium, and low) to evaluate the feasibility and usability of the developed learning media. The second trial involved 85 students to further examine the practicality of the model in classroom implementation. In total, 128 students participated in different stages of the research and development process. However, the effectiveness test using the pretest-posttest design was conducted with a specific group of 35 students who participated in the implementation phase of the developed model.

The effectiveness of the model was analysed using pre-test and post-test scores. The effectiveness of testing employed a one-group pretest-posttest design. To examine the effectiveness of the developed learning model, a smaller group of 35 students participated in the pre-test and post-test experiment. Data were collected through documentation, interviews, questionnaires, tests, and observations. Expert validation was conducted to evaluate the quality of the learning materials, while the practicality of the model was assessed based on teacher and student responses. This design was selected because the primary objective of the study was to evaluate the initial effectiveness of the developed instructional model as part of the development stage in the R&D process. In development-oriented research, preliminary effectiveness testing is commonly conducted using a single-group design to determine whether the prototype model demonstrates potential learning benefits before being tested in a broader quasi-experimental setting.

RESULTS

Analysis Stage

Analysis was very important at different stages of development. The programme's principal objective was to cater to the needs of real elementary school students who were interested in multiliteracy learning. To do the needs assessment, the researcher spoke to teachers, looked over course materials, and went to classrooms. The study discovered that conventional methods of teaching reading and writing hindered pupils' comprehension of abstract concepts. To address these challenges, a strategy was created that integrated technological instruments with public involvement.

Along with the assessment of the requirements, a full front-end analysis was done. The pupils' personalities, the kind of classroom, the amount of technology utilised, and the money all played a part. The results showed that augmented reality was a great way to combine learning, especially because the students were already used to using mobile devices. The present emphasis on multiliteracy in the curriculum facilitates the use of AR-based project-based learning to enhance engagement and comprehension.

The analytical phase also showed that the national curriculum assumed that students already had certain skills, even though this wasn't always the case. The researcher emphasised these distinctions to strengthen the argument for integrating Assemblr Edu and augmented reality into the project-based learning paradigm. The idea was technically good, and kids learned how to get information and develop multiliteracy abilities, which are very important in today's schools, via this procedure.

Design Stage

The findings of the inquiry were turned into a detailed plan for building the AR-based PBL model throughout the design phase. The initial stage was to utilise augmented reality (AR) material in lesson plans, storyboards, and screenplays for multi-literacy activities. Much consideration was given to the SAMR framework throughout the lesson development process. Prior to moving on to problem-based group projects including redefinition and change, they began using augmented reality (AR) capabilities to complement conventional media.

The project team ensured that instructional designers, subject matter experts, and educational IT specialists collaborated, and the plan laid out the timeline for each development step. The media standards, including the way Assemblr Edu will integrate text, images, 3D models, and interactive components, were crystal clear. The product's technical functioning and learning objectives may be guaranteed using this systematic approach.

The review cycles made the first plan better and finished the design process. During the review cycles, the researcher and experts may carefully look at the proposed things to see whether they are easy to understand, valuable, and consistent. This ensured that the model would be both technically advanced and educationally beneficial. With this done, it might go on to the development phase, where it could be brought to life and tested.

Development Stage

The blueprint design was transformed into a working learning product throughout the development stage. The SAMR framework was utilised to connect the Problem-Based Learning approach with Assemblr Edu Augmented Reality. Currently, the prototype is a product of the integration of text, graphics, 3D models, and interactive elements that support multiliteracy goals. Once the initial prototype was completed, expert validation was carried out to ensure both the material and the media met academic and practical standards. The results of material and media expert validation are summarised in the following tables.

The findings of the material expert validation in Table 1 showed that the average feasibility percentage was 86.67%, which was considered extremely possible. This result showed that the material was very similar to what was taught in class, theoretically correct, and at the right level for fourth graders. The experts also pointed out how clear the information was, how well it was organised, and how well the examples fit.

Table 1
Results of material expert validation

No.	Rated Aspect	Score		V (%)
		TS	*TSh*	
	Content Suitability			
1.	The material presented is in accordance with the grade IV curriculum.	3	4	75
2.	The explanation of the material is in accordance with the concept.	4	4	100
3.	The material presented helps to understand the concept.	4	4	100
4.	Material related to the prerequisite concept.	3	4	75
5.	The level of difficulty of the material is in accordance with the abilities of fourth grade students.	3	4	75
6.	The practice questions provided improve students' abilities.	3	4	75
7.	The material presented supports the learning of subsequent material.	4	4	100
8.	The use of the term is correct.	3	4	75
	Presentation of Material			
9.	The material is presented clearly and is easy to understand.	3	4	75
10.	The material is arranged systematically and sequentially.	3	4	75
11.	The examples given support understanding of the material.	3	4	75
12.	The language used is simple and appropriate to the characteristics of fourth grade students.	4	4	100

Table 1 (*continued*)

No.	Rated Aspect	Score		V (%)
		TS	***TSh***	
	Interaction and Display			
13.	The application display is attractive and supportive learning.	4	4	100
14.	The application supports student understanding.	4	4	100
15.	The application allows students to actively interact.	4	4	100
	Total Score	52	60	1300
	Average Percentage			86.67

This validation made sure that the model met the requirements that were found during the analysis stage, especially when it came to helping students build multiliteracy via clear and useful instructional material.

In terms of media validation as shown in Table 2, the application achieved an overall score of 81.25%, which was considered *feasible*. Attractive displays, functional color schemes, and interactive components that engaged pupils were all strengths of the visual design. The experts, on the other hand, suggested changes to the design, navigation, and readability of the content to make it easier to use. The product is good for usage in the classroom as is, but it might be improved to better fit the many ways that children learn.

Table 2
Results of media expert validation

No.	Rated Aspect	Score		V (%)
		TS	***TSh***	
	Display Design			
1.	The application display is attractive and suits the characteristics of elementary school students.	3	4	75
2.	The choice of colors supports comfort in using the application.	3	4	75
3.	Layout (*layout)* well organised.	3	4	75
4.	Text size is easy for students to read.	3	4	75
5.	The image size is clearly visible.	3	4	75
6.	The use of animations, pictures and *icon* according to learning.	3	4	75
	User Interaction			
7.	The application allows students to actively interact with learning materials.	4	4	100
8.	Application response to student interactions (clicks, feedback) back, etc.) went smoothly.	3	4	75
9.	Feedback is available when students conduct learning evaluations.	4	4	100

Table 2 (*continued*)

No.	Rated Aspect	Score		V (%)
		TS	*TSh*	
	Ease of Use			
10.	The application is easy to access and use by students.	3	4	75
11.	The app usage guide is clear and easy to follow.	3	4	75
12.	Navigation between menus and features within the application is not confusing.	3	4	75
13.	The application is easy to install (in *install)* and run on the android device.	3	4	75
14.	There are no technical difficulties that hinder media use.	3	4	75
	Product Effectiveness			
15.	Media supports the development of students' counting skills.	4	4	100
16.	Effective application used in independent activities.	4	4	100
	Application Performance			
17.	The application runs stably without any interruptions during used.	3	4	75
18.	The application has access speed when used by students.	3	4	75
19.	Features/buttons in the app are working fine.	3	4	75
20.	The application supports the use of offline (without internet connection).	4	4	100
	Total Score	65	80	1625
	Average Percentage			81.25

It was determined that the prototype was both technically possible and helpful for teaching how to use both materials and media in a combined way. Because of the high percentages, we know it's time to test the product in actual classrooms with real instructors and kids to see how it works. This step showed how important it is to get advice from experts in the Lee and Owens model. Before it became widely used, this made sure that the learning tool was of good quality.

Implementation Stage

The implementation stage was carried out to evaluate the practicality of the developed PBL model integrated with Assemblr Edu AR based on the SAMR framework. After being validated by experts, the product was tested in real classroom settings involving both teachers and students. This phase aimed to examine the extent to which the application could be effectively used in multiliteracy learning. Practical assessments were conducted through questionnaires and observations, with responses gathered from teachers and students. The results are presented in the following tables.

The practicality test by teachers based on Table 3 yielded an average score of 91.67%, which was categorised as *very practical*. Teachers reported that the

Table 3
Results of practicality by teachers

No.	Rated Aspect	Score		V (%)
		TS	*TSh*	
	Application View			
1.	The text on the application is easy to read for fourth grade students.	3	4	75
2.	The use of color in the application is interesting and not disturbing students' concentration.	4	4	100
3.	The layout and arrangement of the application content is consistent and easy for students to understand.	4	4	100
4.	The menus and buttons on the application are easy to operate fourth grade students.	4	4	100
	Content			
5.	The material in the application is in accordance with the learning outcomes of the independent curriculum.	3	4	75
6.	The practice questions presented are relevant to the material has been delivered.	4	4	100
7.	The questions presented have a level of difficulty that is appropriate to the students' abilities. class IV	4	4	100
	Interaction			
8.	The application provides an interactive and engaging learning experience for students.	4	4	100
9.	The application provides educational feedback for student answers, both right and wrong.	4	4	100
10.	The application can maintain student engagement throughout the learning process.	4	4	100
	Usage			
11.	The application runs stably without any interruption.	3	4	75
12.	The user guide is presented clearly and easily understood.	3	4	75
13.	The application can be accessed and downloaded easily.	3	4	75
	Usefulness			
14.	The application helps students understand the concept.	4	4	100
15.	Applications improve students' skills.	4	4	100
	Total Score	55	60	1375
	Average Percentage			91.67

application was easy to operate, the menus and buttons were accessible for fourth-grade students, and the content was consistent with the learning outcomes of the independent curriculum. They also stressed that the practice questions in the application were useful, tough, and helped students improve their multiliteracy abilities. This study showed that the approach not only helped instructors reach their teaching objectives, but it also fits perfectly into their teaching styles.

The students' viewpoint in Table 4 showed that the practicality exam had an even higher average score of 97.14%, which means it was highly useful. Students said that the app was simple to use, looked well, and helped them comprehend learning ideas. The interactive feedback from the AR software also made them more interested in and confident in their learning by encouraging them to become more involved with the topic. This high level of acceptance among students suggested that the application successfully addressed their needs and preferences, which were identified during the analysis stage. The results of teacher and student practicality tests confirmed that the developed AR-based PBL model was highly feasible for classroom use. Both groups said the programme was useful, interesting, and easy to use. This phase confirmed the design and development choices made earlier in the Lee and Owens model and gave solid proof that the product was ready to be evaluated for its efficacy in the next assessment stage via pre-test and post-test evaluations.

Table 4
Results of practicality by students

No.	Rated aspect	Score		V (%)
		TS	***TSh***	
	Ease of Use			
1.	This application is easy to use.	33	35	94.28
2.	The usage guide in this application is clear and easy to follow.	34	35	97,14
3.	I did not experience any technical difficulties while using this application.	32	35	91,42
	Benefits of Learning			
4.	This app helps me understand the concept better.	33	35	94.28
5.	I feel helped by this application to study the material.	34	35	97.14
6.	This app gives good explanations when I make a mistake.	34	35	97.14
	Application View			
7.	The application has an attractive and easy-to-understand appearance.	34	35	97.14
8.	Colors, icons, layout and use of text chosen to make it easier for me to use.	34	35	97.14
	Motivation to learn			
9.	This app makes me more interested in learning.	35	35	100
10.	I feel more confident working on questions after using this application.	34	35	97.14
	Application Effectiveness			
11.	This application helps me practice questions faster and more accurately.	34	35	97.14
12.	This application can be used anytime and anywhere.	34	35	97.14
	Total Score	405	420	1157.1
	Average Percentage			97.14

Evaluation Stage

The evaluation stage was the last step in the Lee and Owens development methodology. It was meant to see how well the PBL model worked with Assemblr Edu AR inside the SAMR framework. After being vetted by specialists and confirmed as practical by instructors and students, the product was evaluated using a one-group pretest-posttest approach. This assessment determined the extent to which the application enhanced students' multiliteracy abilities by analysing their performance before and subsequent to using the established model. Table 5 shows the outcomes of the pre-test and post-test.

The results of the pre-test and post-test in Table 5 indicated a huge increase in students' learning outcomes. The average score rose from 69.43 on the pre-test to 93.23 on the post-test. The results above present the statistical evidence of students' learning improvement. The following discussion interprets these findings in relation to the pedagogical framework and technological integration used in this study.

To evaluate the effectiveness of the developed learning model, a paired sample t-test was conducted to compare students' pre-test and post-test scores. This statistical analysis was used to determine whether there was a significant difference in students' multiliteracy learning outcomes before and after the implementation of the Problem-Based Learning model integrated with Augmented Reality based on the SAMR framework. The descriptive statistics and results of the paired sample t-test are presented in Table 6.

Table 5
Results of pre-test and post-test

No.	Students Number	*Pre-Test*	*Post-Test*
1.	S 1	55	81
2.	S 2	42	78
3.	S 3	65	90
4.	S 4	87	100
5.	S 5	92	100
6.	S 6	77	91
7.	S 7	45	95
8.	S 8	100	100
9.	S 9	45	86
10.	S 10	73	91
11.	S 11	45	82
12.	S 12	68	91
13.	S 13	95	100
14.	S 14	55	95
15.	S 15	86	95
16.	S 16	86	100
17.	S 17	100	100

Table 5 (*continued*)

No.	Students Number	*Pre-Test*	*Post-Test*
18.	S 18	73	95
19.	S 19	64	86
20.	S 20	55	95
21.	S 21	59	100
22.	S 22	50	86
23.	S 23	51	82
24.	S 24	54	82
25.	S 25	73	100
26.	S 26	95	100
27.	S 27	77	95
28.	S 28	50	100
29.	S 29	45	86
30.	S 30	100	100
31.	S 31	82	95
32.	S 32	100	100
33.	S 33	45	95
34.	S 34	55	91
35.	S 35	86	100
	Amount	2430	3263
	Rate-rate	69.43	93.23

Table 6
Effectiveness test

Test	N	*Mean*	*SD*	*T-Value*	*P-Value*
Pre-Test	35	69.43	19.60		
Post-Test	35	93.23	6.90	-9.06	<0.001

The effectiveness of the developed learning model was examined using a paired sample t-test to compare students' pre-test and post-test scores. As presented in Table 6, the mean score increased from 69.43 in the pre-test to 93.23 in the post-test, indicating a substantial improvement in students' multiliteracy learning outcomes. The results of the paired sample t-test revealed that the difference between the pre-test and post-test scores was statistically significant ($t = -9.06$, $p < 0.001$). This finding demonstrates that the Problem-Based Learning model integrated with Augmented Reality based on the SAMR framework significantly improved students' multiliteracy learning outcomes.

Multiple qualitative assessments conducted throughout the deployment phase confirmed the strategy's effectiveness. After doing literacy-based tasks, students' natural drive, confidence, and ability to work together improved. Also, instructors saw that when students utilised augmented reality tools, they took part in class discussions more and were better able to integrate what they learned in real life. The learning model supported the development of students' multiliteracy skills by encouraging them to interpret information through multiple modes, including visual, textual, and interactive representations.

The evaluation phase used the Lee and Owens paradigm to validate the overall effectiveness of the development process. The PBL paradigm's effectiveness and compatibility with AR Assemblr Edu were shown by the favorable comments from students and instructors and the high exam results. Our results underscore the need to deliberately integrating new technologies into educational frameworks like SAMR to provide primary school pupils with learning experiences that are relevant, creative, and future-oriented.

The improvement in students' learning outcomes can be explained by several pedagogical aspects of the developed model. First, the integration of the Problem-Based Learning approach encouraged students to actively engage in problem-solving activities and collaborative discussions. Through this process, students were required to analyse information, construct arguments, and communicate ideas, which are key components of multiliteracy learning. This finding supports previous studies indicating that problem-based learning can foster higher-order thinking skills and meaningful learning experiences.

Second, the use of Augmented Reality through the Assemblr Edu platform enriched the learning environment by providing interactive and visual representations of learning materials. Augmented Reality allows abstract concepts to be presented in more concrete and engaging forms, enabling students to explore learning content in a more immersive way. This technological integration aligns with the transformation stage of the SAMR framework, where technology is not merely used as a substitution but significantly transforms the learning experience.

The improvement in students' learning outcomes can also be interpreted through the perspective of the SAMR framework. The integration of Augmented Reality in this study did not merely function as a substitution for traditional learning media but enabled a transformation of the learning process. At the modification and redefinition levels of the SAMR model, technology allows the creation of learning experiences that would be difficult to achieve through conventional instruction. Through the use of Augmented Reality, students were able to explore interactive visual objects, engage in problem-based tasks, and collaboratively construct meaning. This technology-supported learning environment encouraged students to actively interpret information across multiple modes, which is a fundamental aspect of multiliteracy learning.

DISCUSSION

Our findings demonstrate the feasibility and efficacy of a novel SAMR-based Problem-Based Learning (PBL) methodology for teaching primary school students multiliteracy via the use of Assemblr Edu AR. Subject matter experts validated the model at a validation score of 86.67%, which means that it is "very feasible," while media experts scored it at 81.25%, regarded as "feasible." Teacher and user practicality tests also proved extremely high satisfaction at levels of 91.67% and 97.14%, respectively, classified as "very practical." In addition, by adopting a one-group pretest-posttest experimental design, the effectiveness observation indicated an extraordinary rise in student achievement from an average of 69.43 to an average of 93.23. These results are consistent with earlier studies that recommend the use of AR as well as multiliteracies in educational paradigms that enhance the transformative capability of AR in elementary learning (Ang & Tan, 2020; Cai et al., 2022; Kulju et al., 2018).

Although the validation and practicality scores obtained in this study were relatively high, these results should be interpreted with caution. High validation scores may partly reflect the limited number of expert validators involved in the evaluation process, which could influence the overall assessment. Similarly, the high practicality ratings from teachers and students may have been affected by the novelty of the Augmented Reality technology and the interactive features of the Assemblr Edu platform, which tend to increase initial enthusiasm during implementation. Therefore, future studies should involve a larger number of validators and conduct longer-term classroom implementations to examine the consistency and sustainability of these findings.

Existing scholarship has also asserted that the multiliteracies approach shifts the learning's centre of attention from the acquisition of contents alone towards active designing and critical interaction of learners with a variety of media types and forms of text (Ang & Tan, 2020; Kulju et al., 2018). Our findings from the PBL model are in line with those of Dewi et al. (2023), who highlighted digital storytelling as an aspect of multiliteracies that linked students' narrative identities to their learning processes. Ganapathy and Seetharam (2016), and Ghimire and Pandeya (2020) say that there are numerous ways to successfully apply a multiliteracy strategy in the classroom. This is in line with the main idea of the SAMR model, which says that technology allows for deep and engaged thought. Augmented reality (AR) apps truly shine at the Redefinition stage because they provide people with new ways of looking at things and new ways of framing problems (Chen, 2019; Dalia & Jamilah, 2024).

Students' scores showed a significant improvement, proving that combining PBL modeling with AR is a successful way to improve learning after the intervention.

The results of this study corroborate those of another meta-analysis that found AR to have great potential in assisting the learning of children, especially younger ones and augmented reality (AR) had a more significant impact on early learners than teens, proving that AR is beneficial across all educational levels, not only higher school (Cai et al., 2018). Elementary school students can better grasp complex concepts when they use augmented reality (AR). This provides support for the idea that augmented reality might be a helpful tool for those who need to read and write in more than one language to make sense of complex circumstances (Sudirman, 2022).

According to Runisah et al. (2022), the iterative design cycle of the Lee and Owens approach emphasises formative assessment cycles to support the progressive refinement of education. Our PBL framework's inclusion of AR aligns with this cycle. According to Rodríguez-Martínez et al. (2022), in order to put our results into practice, we need to systematically use augmented reality technology, especially in order to create personalised, interactive learning spaces that cater to the distinct needs of every student. Hung et al. found that 97.14% of students and 91.67% of teachers think the technique is great. Effective educational systems, according to Hung et al. (2016), must constantly evolve to include new technologies.

This study offers a meaningful theoretical contribution to the fields of educational technology and multiliteracy pedagogy by integrating Augmented Reality (AR) through the Assemblr Edu platform with the Problem-Based Learning (PBL) model and the SAMR (Substitution, Augmentation, Modification, and Redefinition) framework. While the SAMR model has traditionally been conceptualised as a guideline for technology integration, this study operationalises it into a structured, evidence-based approach for multiliteracy instruction in elementary education. The alignment between PBL stages and SAMR levels demonstrates how technology can move beyond substitution toward transformation. Specifically, digital media replace conventional materials at the substitution stage, interactive elements enhance engagement at the augmentation stage, collaborative problem-solving using AR occurs at the modification stage, and students ultimately create new forms of multimodal outputs at the redefinition stage. This integration positions SAMR not merely as a conceptual model but as a practical pedagogical framework that connects technology use with cognitive and literacy development.

Furthermore, this study extends multiliteracy theory by illustrating how the combination of AR and PBL fosters students' ability to interpret, analyse, and produce multimodal texts. The findings suggest that digital transformation in learning should not be limited to media enhancement but should involve the redesign of learning experiences that promote contextual understanding, interaction, and higher-order thinking. Supported by iterative validation and evaluation processes consistent with the

Lee and Owens instructional design model, the study demonstrates both pedagogical coherence and technological feasibility. In doing so, it aligns with the New London Group's perspective on multiliteracy by emphasising the integration of visual and verbal modes in meaning-making processes. Overall, this study contributes to a comprehensive framework that bridges instructional design, pedagogical theory, and digital innovation, offering a theoretically grounded model for advancing multiliteracy learning in technology-rich educational contexts.

In practice, this research provides a useful framework for teachers, curriculum creators, and schools to create and use immersive learning environments that encourage multiliteracy using AR-based PBL. The produced model has been shown to be very practicable (86.67% by material experts and 81.25% by media experts) and useful (91.67% by instructors and 97.14% by students). It is ready to be used in the classroom as an instructional design. It shows how Assemblr Edu may help students understand complex ideas, get them interested, and get them more involved in activities that need several literacies. The methodology helps instructors move away from conventional, text-based teaching and toward interactive, inquiry-based learning that is assisted by AR. The results show that legislators and school administrators need to give teacher training and digital infrastructure that make it easier for AR to be used in the classroom. The research also helps teachers grow professionally by providing proof that AR-driven multiliteracy learning greatly boosts student success (from 69.43 to 92.43 on average) and motivation.

These results align with contemporary studies investigating the effects of technology-enhanced pedagogical approaches, including project-based learning, multiliteracy training, and augmented reality education. The findings of this study reinforce the growing body of research on technology-enhanced pedagogy, particularly in the integration of augmented reality (AR), multiliteracy learning, and problem-based approaches. Previous studies have demonstrated that AR can enrich conventional instructional practices and improve student engagement and learning outcomes (Cahyana et al., 2023; Carrión-Robles et al., 2023; Nugroho et al., 2024). In line with multiliteracy theory, students are required to develop the ability to interpret and produce meaning across diverse modes of communication, as emphasised by the New London Group (Rosyidah et al., 2023). The significant improvement in student performance (69.43 to 93.23) observed in this study supports the shift from traditional literacy approaches toward multiliteracy-oriented instruction. Furthermore, the integration of AR within the Problem-Based Learning (PBL) model, guided by the SAMR framework, demonstrates how technology can transform learning from conventional practices into interactive, student-centred experiences, consistent with findings by Guo and Kim (2022) and Miguel-Alonso et al. (2024).

Our study, which showed a large boost in scores (from 69.43 to 93.23), demonstrates that we should stop using traditional literacy frameworks and start using a multiliteracy approach. From an implementation perspective, this study highlights the practical feasibility of integrating AR platforms such as Assemblr Edu into elementary school classrooms to create immersive and adaptive learning environments. The results align with instructional design principles proposed by Lee and Owens and are supported by prior studies emphasising the effectiveness of structured, technology-based learning interventions (Ersözlü et al., 2019; Mursyida et al., 2023; Nugroho et al., 2024). Positive student responses and improved learning outcomes indicate that such approaches can enhance engagement and foster meaningful learning experiences. However, the study was limited to a single institutional context, which may affect generalisability (Sari et al., 2021). Therefore, future research should explore broader implementations across diverse educational settings and conduct longitudinal studies to examine sustained impacts (Anuar et al., 2021; Guse & Zobitz, 2010; Maulyda et al., 2024). Overall, the findings suggest that integrating AR and PBL offers a promising direction for developing students' multiliteracy competencies and preparing them for the demands of an increasingly digital learning environment.

In addition to pedagogical considerations, the practical implementation of this learning model requires several technical supports. Schools need to ensure the availability of digital devices such as tablets or smartphones that are capable of running Augmented Reality applications such as Assemblr Edu. Stable internet connectivity is also necessary for accessing and downloading AR learning content. Furthermore, teachers need basic digital literacy skills to design and implement AR-based learning activities effectively. Providing professional development programmes and technical support for teachers may help facilitate the successful adoption of this model in elementary school classrooms.

CONCLUSION

In summary, the findings demonstrate the SAMR framework and combining Problem-Based Learning (PBL) with Assemblr Edu Augmented Reality (AR), approach is practical, effective, and a feasible solution to the difficulties encountered in multiliteracy teaching. AR and SAMR might really revolutionise the way classrooms are set up, such as encouraging kids to be creative, work together, and be active. The model was deemed technically and pedagogically sound by experts in the field as well as those who specialised in the subject area. 86.67% thought it had a good chance of succeeding, and 81.25% thought it was possible. The programme performed well on the practicality test, with 97.14% of students and 91.67% of instructors expressing their satisfaction. In other words, the technology was easy to use and the pupils had fun while studying. The effectiveness test also indicated that the students' multiliteracy abilities became better. The mean score went from 69.43 on the pretest to 93.23 on the posttest, which shows that the programme worked.

Despite the promising results, this study has several limitations. The effectiveness testing was conducted using a one group pretest posttest design without a control group. Consequently, the observed improvement in students' multiliteracy skills cannot be fully attributed to the developed model alone, as other external factors may also have influenced the outcomes. Therefore, this study should be considered a preliminary pilot implementation of the developed learning model. Future research should involve a quasi-experimental design with a control group and a larger sample size to provide stronger empirical evidence regarding the effectiveness of the model.

The findings of this study also provide several practical implications for elementary school teachers. The significant improvement in students' learning outcomes suggests that integrating Problem-Based Learning with Augmented Reality can support students in interpreting information through multiple modes, including visual, textual, and interactive representations. Teachers can utilise platforms such as Assemblr Edu to design contextual learning activities that encourage students to explore problems, visualise abstract concepts, and collaboratively construct knowledge. The integration of the SAMR framework can help teachers systematically plan the level of technology integration, moving from simple technology substitution toward more transformative learning experiences.

This study also opens several directions for future research. First, future studies are recommended to employ comparative or quasi-experimental research designs involving control groups to provide stronger evidence of the effectiveness of the proposed learning model. Second, further research could examine the implementation of the model in broader educational contexts, including different grade levels, schools, or regions, to explore its generalisability. Third, longitudinal studies are needed to investigate the long-term impact of integrating Augmented Reality and Problem-Based Learning on students' multiliteracy development and critical thinking skills. Such studies would provide deeper insights into the sustainability of technology-integrated instructional models in elementary education.

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