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Table Of Contents

Journal Cover	1
Author[s] Statement	3
Editorial Team	4
Article information	5
Check this article update (crossmark)	5
Check this article impact	5
Cite this article.....	5
Title page	6
Article Title	6
Author information	6
Abstract	6
Article content	7

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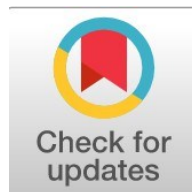
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Augmented Reality Learning Board Fits Intellectual Disability Cognitive Needs

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Abstract

General Background: Students with intellectual disabilities require concrete, visual, repetitive, and low-load learning media to support basic literacy and numeracy development. **Specific Background:** Existing classroom media did not fully match students' cognitive characteristics, including perception, attention, memory, and response, making basic cognitive learning less optimal. **Knowledge Gap:** Previous augmented reality learning media studies have not sufficiently integrated cognitive ergonomics and user-centered design to adjust interface, interaction, comfort, and usability for students with intellectual disabilities. **Aims:** This study aimed to design an Augmented Reality-based Cognitive Learning Board adapted to the needs and cognitive characteristics of elementary students with intellectual disabilities. **Results:** Using a qualitative approach, cognitive ergonomics, and user-centered design stages, the prototype was tested on five students. After design iteration, comprehension time decreased to 20 seconds in numeracy and 21 seconds in literacy, task completion time decreased to one minute, instruction repetition decreased to one and two times, error rates decreased to 20% and 40%, focus duration increased to four minutes, and distractions decreased to two times. **Novelty:** This study integrates augmented reality, cognitive ergonomics, and user-centered design for basic cognitive learning media. **Implications:** The prototype provides practical guidance for inclusive media design that is easier to use, more interactive, and aligned with intellectual disability learning needs.

Highlights:

- Task completion decreased to one minute after iteration.
- Error rates declined in both numeracy and literacy trials.
- Student focus increased while distraction frequency decreased.

Keywords: Augmented Reality, Cognitive Ergonomic, Intellectual Disability, Learning Media, User-Centered Design

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Introduction

Students with intellectual disabilities have limitations in intellectual functions that impact their ability to understand academic concepts, particularly in basic cognitive learning for numeracy and literacy. Basic cognitive learning is the main foundation for students with intellectual disabilities in enhancing academic abilities and independence in daily life. This aligns with research stating that strengthening literacy and numeracy in individuals with intellectual disabilities is related to increased participation in activities and aspects of independence in everyday activities in a tangible way [1]. At SLB Paedagogia, the process of basic cognitive learning is carried out through the implementation of learning media as a supportive tool for the learning process. Some examples of media used are visual cards, pop-up books, learning videos, PowerPoint, and the use of concrete objects. This is demonstrated through the level of learning achievement of 5 students with intellectual disabilities in basic cognitive learning of numeracy and literacy that can be seen in figure 1.

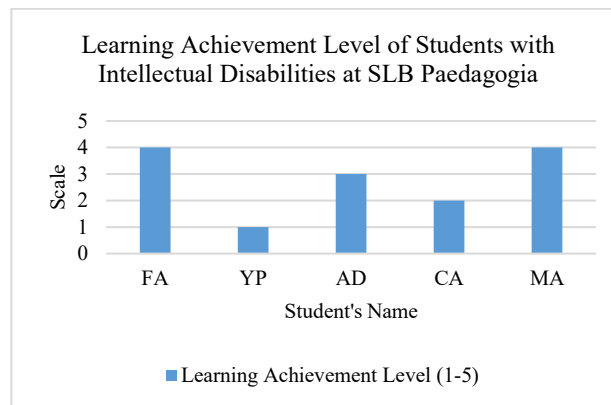


Figure 1. Learning Achievement Level of Students with Intellectual Disabilities at SLB Paedagogia

The image above shows that the students' learning achievement levels have not yet reached the maximum achievement. Individuals with intellectual disabilities have limitations that affect daily activities and social interaction.

[2]. Students with mental disabilities have limitations in memory and understanding of abstract concepts, so they require learning that is concrete, visual, repetitive, and has minimal cognitive load [3]. Based on these conditions, it indicates the need for the development of basic cognitive learning media that not only supports the learning process but also meets the students' cognitive needs. This study focuses on 5 intellectually disabled elementary school students at SLB Paedagogia without any other disabilities. The development of this media is not only intended to meet the needs of students with intellectual disabilities at SLB Paedagogia, but also the size of this group's population. Based on statistical data from 2025 regarding the number of students with disabilities at the elementary school level, it was recorded at around 67,8 thousand of students [4], thus requiring special attention in providing appropriate learning media. Therefore, cognitive ergonomics plays an important role in the design of this learning media. Cognitive ergonomics in the design of this learning media focuses on adjusting tools to the user's cognitive abilities, namely perception, attention, memory, and the user's responses to the system [5].

Through this research, the development of basic cognitive learning media is carried out, specifically tailored to the learning characteristics of students with intellectual disabilities in elementary school, namely an Augmented Reality-based Cognitive Learning Board focusing on the introduction of letters and numbers through simple concepts and without delving deeply into affective and psychomotoric aspects. This learning media integrated with Augmented Reality technology allows the projection of contextual data that is customized, giving users the ability to visually observe and interact with virtual objects in the real world [6]. In the context of learning media for children with intellectual disabilities, Augmented Reality has the potential to improve the quality of visual perception, help maintain attention through interactive stimuli, support memory reinforcement through concrete representations, and facilitate active student responses in the learning process.

Various studies have shown that interactive learning media, particularly those based on Augmented Reality, have great potential in supporting the learning of children with intellectual disabilities because they can present material in a visual, concrete, and engaging manner. Previous research has shown that the game-based augmented reality learning media that was developed is stated to be very valid, very practical, and very effective in improving the basic math skills of students with intellectual disabilities [7]. Other research shows that the use of AR media is able to increase attention, interest in learning, as well as children's engagement in the social communication learning process for children with special needs [8]. However, that research has not examined the application of cognitive ergonomics approaches and user-centered design methods in the development of learning media. In particular, previous studies have not explored how these approaches can be utilized to enhance user comfort, reduce cognitive load, and improve the overall learning experience through interfaces and interactions that are tailored to users' needs and characteristics.

This study aims to design a learning media that can be adapted to the needs and cognitive characteristics of students with intellectual disabilities. In addition, the media can help improve cognitive abilities in supporting the learning process of students with intellectual disabilities. This study provides theoretical contributions in enriching the literature in the field of cognitive ergonomics and industrial engineering product design, as well as offering practical guidance for other learning media developers, particularly in the context of students with intellectual disabilities and the implementation of Augmented Reality technology.

Method

A. Research Approach

This research is a qualitative study aimed at gaining an in-depth understanding of the learning process, abilities, and characteristics of students with intellectual disabilities in order to produce media that can meet their cognitive needs. In the design of this media, a user-centered design method is used through four stages: Discovery, Definition, Development, and Delivery [9]. This method is integrated with a cognitive ergonomics approach to ensure that the design aligns with students' perception, attention, memory, and response abilities to the media. Data were collected through observations, interviews, and usability testing. The usability evaluation was conducted based on Nielsen's theory, which includes five variables: learnability, efficiency, memorability, errors, and satisfaction [10]. In addition, observations were carried out to evaluate cognitive load, task performance, and students' attention while interacting with the prototype. To ensure data validity, the study applied data triangulation by comparing findings from observations and interviews. The collected data were analyzed qualitatively through data reduction, categorization, interpretation, and conclusion drawing to identify usability issues and determine the suitability of the media design for students' cognitive characteristics. This analytical process provides a more explicit methodological justification for evaluating the effectiveness and usability of the developed learning media.

B. Variable Identification and Definition

In this study, variables function as a conceptual framework and the focus of the research boundaries becomes the basis for the preparation of instruments, data collection, and analysis of research results. There are two types of variables in this study:

1. Independent variable

The independent variable is a variable that can influence the dependent variable. The independent variable in this study is the Cognitive Learning Board media based on Augmented Reality.

2. Dependent variable

The dependent variable is the variable that is influenced or becomes the consequence of the independent variable. The dependent variable in this study is the effectiveness of using learning media based on cognitive ergonomics aspects and usability testing.

C. Data Collection Sources

In this study, the data collected included primary data and secondary data. The data collection techniques are as follows:

1. Primary Data

Primary data is data obtained through direct observation, namely observation and interviews with the selected research objects. The observation stage was carried out twice, namely the initial observation in the school media and the observation of the prototype trial results. Then, the interview stage was also conducted twice, namely the user needs identification interview and the usability test interview.

2. Secondary Data

Secondary data is data obtained from documents and records that are already available in the field. This data includes literature and academic journals as a theoretical basis and previous studies, as well as official school documents covering student profiles and lesson plan (RPP) curriculum.

Result and Discussion

A. Discovery

At this stage, a process of identifying user needs is carried out with the data obtained collected through initial observation activities on school media, interviews to identify user needs, and documentation studies of student profiles and Curriculum Lesson Plans (RPP).

1. Results of Observation

Observation activities were conducted by observing the implementation of one of the learning media used in the student learning process, namely picture cards for Mathematics and Bahasa Indonesia. The aspects measured were Cognitive Load [11], Task Performance [12], and Attention [13]. The observation results for each aspect were obtained from the average of 5 students and served as a reference for testing the prototype that had been developed by comparing the initial condition results and the prototype test results [14]. The observation result can be seen at the table 1.

Table 1. Observation Data of Learning Card Media for Mathematics and Bahasa Indonesia

No	Aspect	Indicator	Results (Mathematics)	Results (Bahasa Indonesia)
1	Cognitive Load	Comprehension time	29 Seconds	27 Seconds
		Repetition of instructions	3 Times	3 Times
2	Task Performance	Task completion time	2 Minutes	2 Minutes
		Error rate	60%	60%
3	Attention	Focus duration	3 Minutes	3 Minutes
		Distraction	4 Times	3 Times

2. Interviews Results

After observation, an interview was conducted with the accompanying teacher regarding the needs, abilities, and characteristics of the users, namely students with intellectual disabilities. The answers from the interview were used as a basis for formulating the user persona and design specifications. The interview results indicate that students' initial abilities in recognizing letters and numbers vary, ranging from the basic stage that requires intensive guidance to students who are already able to read, write, and perform advanced calculations. In terms of perception, students find it easier to understand simple visual displays that are not cluttered, with bright colors, large letters, and concrete images. Students' attention abilities tend to be limited and easily distracted, but can improve with engaging, interactive media and varied activities. Regarding memory, some students are able to remember material after a few repetitions, while others require more consistent repetition and visual aids. Student responses are generally better when supported by visual media and guidance, although some still need direct instruction. Additionally, cognitive load increases when students are faced with long, complex instructions or overly cluttered displays. Therefore, the suitable learning media are those that have simple visuals, brief and clear instructions, accompanied by repetition, as well as interactive elements to enhance student interaction.

3. Documentation Study Results

Based on the documentation study, results were obtained from the student profile data as well as the Lesson Plan (RPP) documents for the Mathematics and Bahasa Indonesia. The data collected shows that the research subjects are students with special needs in the mild to moderate intellectual disability category, with an age range of 9–15 years who are in grades III to VI of elementary school. In mathematics learning, the material provided focuses on number recognition and basic arithmetic operations, using demonstration methods, hands-on practice, and the use of concrete objects. The media used include pictures, cards, real objects, as well as simple digital applications, with learning activities such as counting objects and performing addition based on visual objects. Meanwhile, in Bahasa Indonesia learning, the material is focused on the ability to read two-syllable words taught through drill methods, repetition, and hands-on practice. The media used consists of syllable cards, pictures, and other supporting visuals, with learning activities that emphasize connecting words with pictures as well as practicing reading syllables gradually.

4. Qualitative Data Analysis

The data that has been obtained is then analyzed using the qualitative data analysis method of Miles and Huberman, which includes three stages, namely data reduction, data display, and drawing conclusions [15]. This analysis aims to identify user needs based on cognitive ergonomics principles as a basis for formulating user personas and design specifications in the Definition stage of the User-Centered Design (UCD) method in this study.

At the data reduction stage, the results of observations, interviews, and documentation studies were selected and grouped based on cognitive ergonomics aspects, which include perception, attention, memory, and response. The reduction results indicate that students still experience difficulties in processing information, have relatively short focus durations, high frequency of repetition in understanding the material, and tend to need more time to complete tasks with still high error rates. Interview findings reinforce that students find it easier to understand material through simple, concrete visuals and interactive media. The results of the data reduction are presented in the form of table 2.

Table 2. Data Presentation

No	Aspect	Indicator	Problem	Cause	Design Implication
1	Perception	Comprehension time 27–29 seconds	Difficulty understanding information	Complex visuals	Simplified visuals
2	Attention	Focus ~3 minutes, high distraction	Easily distracted	Less interactive media	Interactive & segmented
3	Memory	Repetition ~3 times	Easily forgets	Lack of reinforcement	Repetition & visual aids
4	Response	Response time 3 minutes, high error rate	Slow response	Lack of interaction	Real-time feedback

The data shows that limitations in perception, attention, memory, and response are interconnected and affect learning effectiveness. Students need simple, structured, and repeated presentations, as well as more interactive media with real-time feedback. Therefore, current learning media are not yet fully compatible with the cognitive characteristics of students with intellectual disabilities, so it is necessary to develop media that are simple, gradual, repetitive, and interactive to enhance attention and response.

B. Definition

At this stage, the process of formulating user personas and design specifications is carried out. User personas are formulated based on the results of data analysis and design specifications are formulated based on user design needs. A user persona was formulated covering user profiles, user characteristics based on cognitive ergonomic principles, the main problems faced by users, and user design needs. The users consist of 5 students with mild to moderate intellectual disabilities, aged 9–15 years, who are elementary school students in grades III–VI of elementary school. The user persona of 5 respondents can be seen from figure 2 to figure 6.

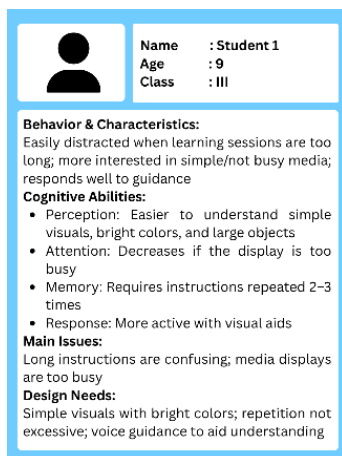


Figure 2. Student 1 Persona

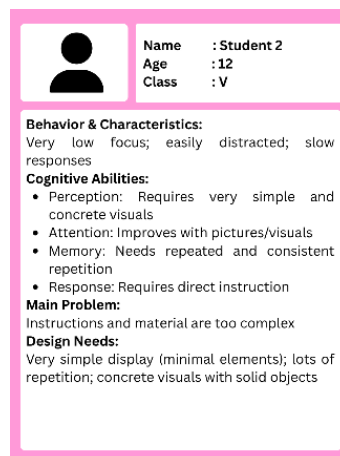


Figure 3. Student 2 Persona

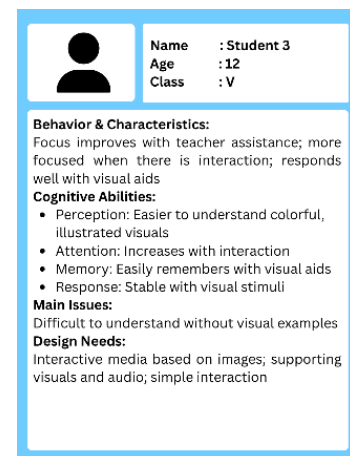


Figure 4. Student 3 Persona

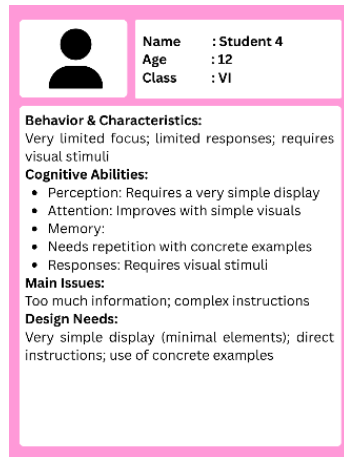


Figure 5. Student 4 Persona

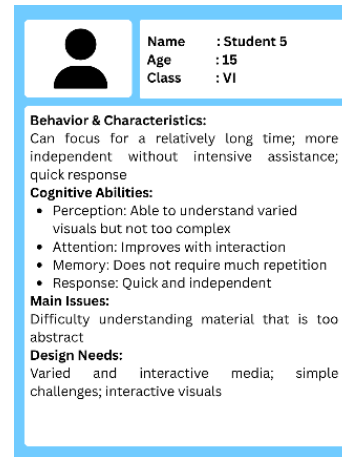


Figure 6. Student 5 Persona

Based on the fifth student user persona, it shows that the average student design need is media with simple visuals, easy for instruction repetition, and interactive with audio guidance and real-time feedback. Design specifications are the basic design concepts formulated based on data analysis to meet user needs which can be seen in table 3.

Table 3. Prototype Design Specification

No	Aspect	Summary Design	AR Features	Prototype Implementation
1	Perception	Simple, concrete visuals	3D objects, soft colors, Scan cards to display 3D AR objects animation, audio	
2	Attention	Minimal and interactive design	AR cards, simple animation, audio	Arrange/select cards to trigger AR visuals
3	Memory	Repetition and step-by-step learning	Clear markers, gradual visuals, feedback	Repeat scanning; staged object display
4	Response	Clear instructions and instant feedback	Touch input, real-time feedback	Select answers on screen with direct feedback

C. Development

At this stage, the process of designing a prototype of the cognitive learning board based on augmented reality is carried out. The design planning includes material concepts, system user flow, mockup design, and prototype implementation.

1. Material Concepts

The material concept is designed to ensure that the learning content aligns with the initial objectives of media design, namely basic cognitive learning in numeracy and literacy. As for the subject for numeracy material, it is the introduction to numbers, counting, and basic addition, and the subject for literacy material is the introduction to letters, reading syllables, and reading simple words. This material concept is designed by adjusting to the skill levels and needs of users, which can be effectively delivered through the designed media. The results of the material concept design can be seen in table 4.

Table 4. Material Concept

No	Material	Sub-Material	Description	Learning Objective	AR Implementation
1	Numeracy	Numbers 1-10	Introduction to number symbols using objects	Students recognize concrete and name numbers 1-10	3D number objects with audio support
2	Numeracy	Counting	Basic counting with concrete representations	Students perform basic counting	Animated objects (e.g., apples, mangoes) representing quantities
3	Numeracy	Basic Addition	Simple addition concepts	Students understand basic addition	Interactive questions (1+1 to 5+5) with touch input and real-time feedback
4	Literacy	Letters A-Z	Introduction to alphabet forms	Students recognize and name letters	3D letter objects with audio support

No	Material	Sub-Material	Description	Learning Objective	AR Implementation
5	Literacy	Syllable Reading	Consonant–vowel combinations	Students read simple syllables	Animated letter combinations (e.g., b + a → ba) with audio
6	Literacy	Simple Word Reading	Combining syllables into words	Students read simple words	Animated word formation (e.g., ba + ca → baca) with audio

2. User Flow

User flow refers to the sequence of steps that students follow, with guidance from teachers, when using the media. It illustrates the entire process, beginning for the initial use of the media and continuing through their interactions with the system. The flow starts with the teacher as a secondary user who selects cards according to the material and the students' skill levels. The card is then placed on the scan area, and the teacher scans it through the AR application to display a 3D object. For materials on numbers, letters, counting, and reading, the system displays a 3D object accompanied by audio, which the students follow according to the activity. The teacher can proceed to the next material gradually. Specifically for basic addition, the system provides questions with answer options and immediate feedback, where students repeat until correct before moving on to the next question until finished. The user flow is presented in the form of a diagram in Figure 7.

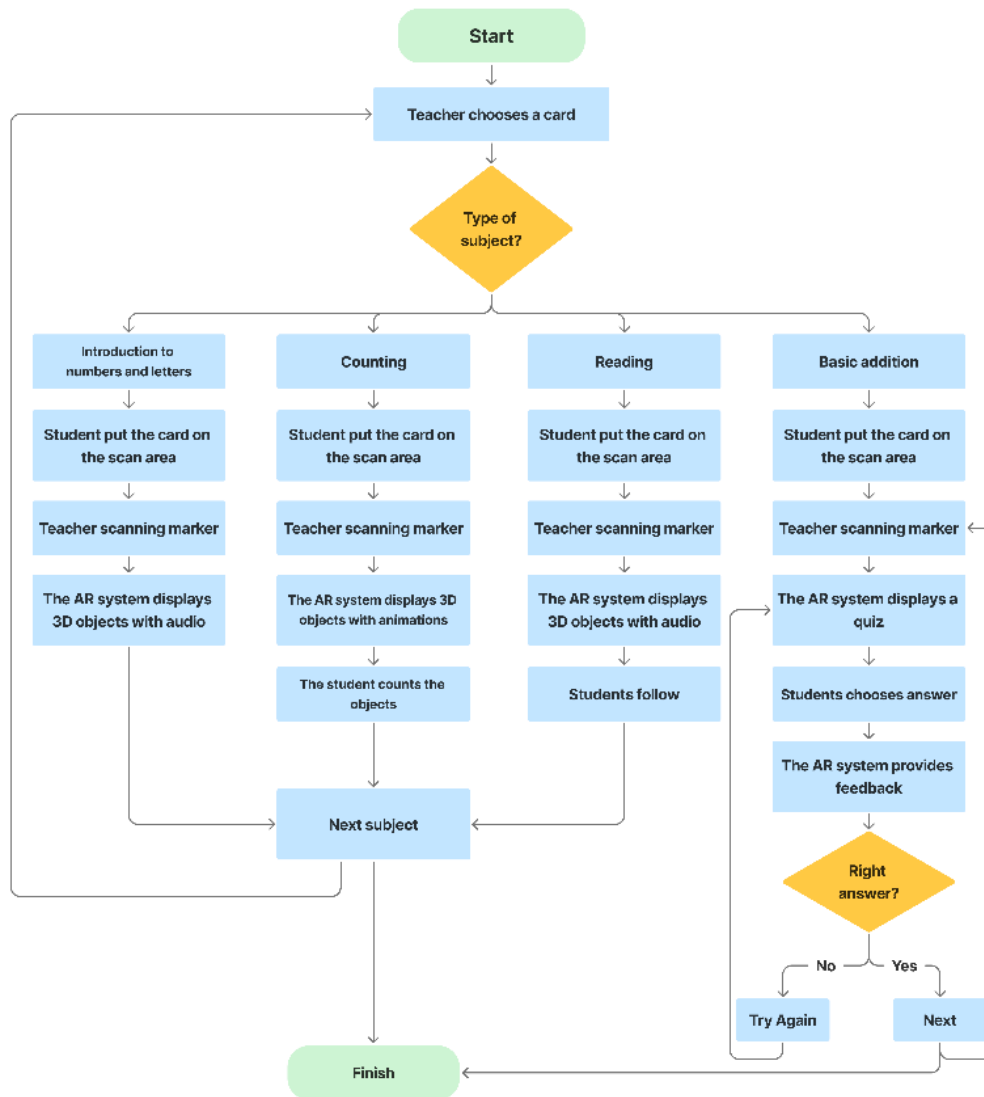



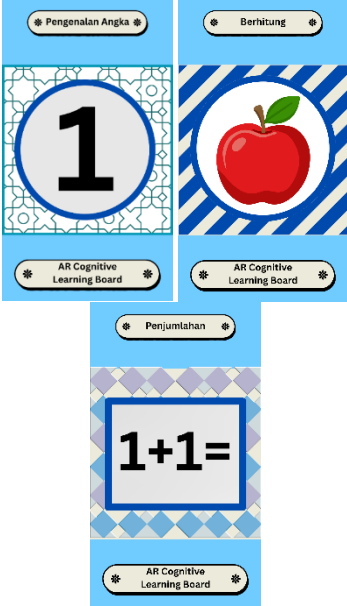
Figure 7. User Flow Diagram

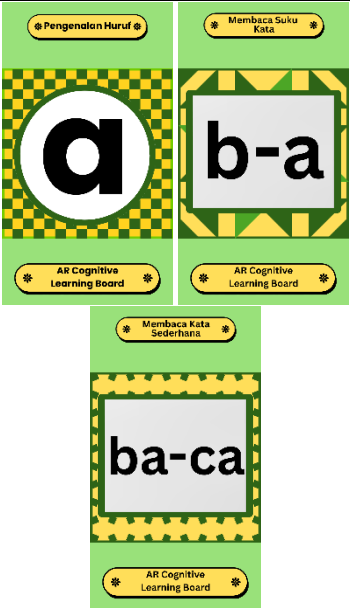
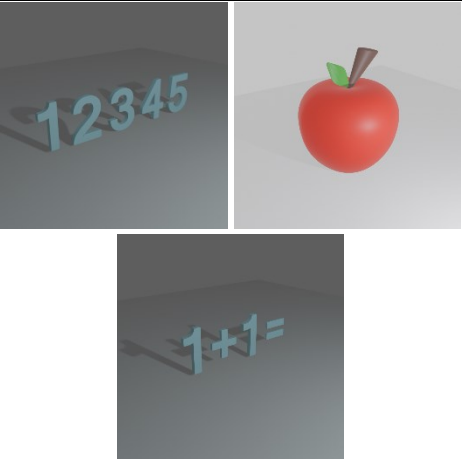
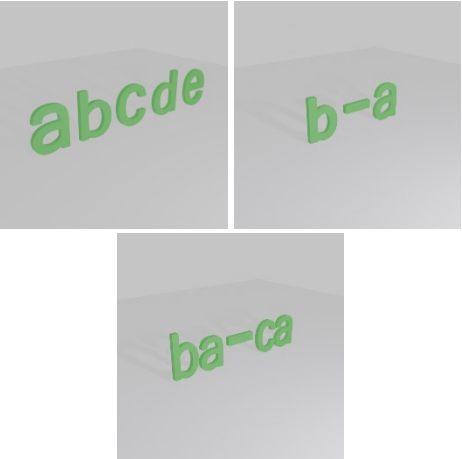
3. Detailed Design

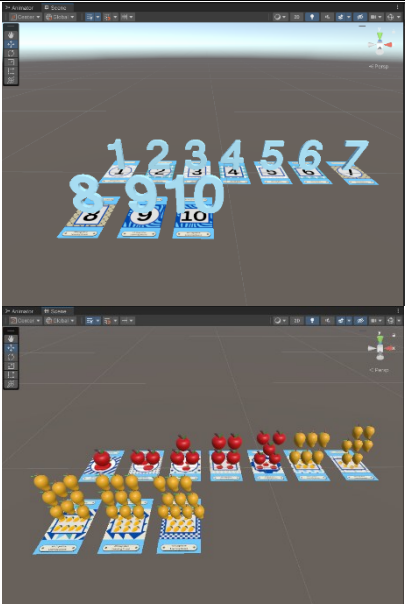
The design that was created includes mockup board design, image marker design, 3D object design, interaction design, and AR visualization. The design is created based on the results of design specification, which can be seen in table 5.


Table 5. Detailed Design

No	Design Component	Sub-Component	Description	Illustration
1	Board mockup design	Technical layout	The layout design measures 40 x 30 cm, divided into six functional areas. The layout division is designed to be simple and structured to help students understand and remember the usage flow and reduce visual distractions.	
	Visual design numeracy		Visual design for numeracy media with bright pastel blue and medium contrast. The choice of bright pastel colors with medium contrast aims to attract the attention of students with intellectual disabilities, reduce distractions, and facilitate the process of visual perception	

No	Design Component	Sub-Component	Description	Illustration
		Visual design literacy	Visual design for numeracy media with bright pastel green and medium contrast. The choice of bright pastel colors with medium contrast aims to attract the attention of students with intellectual disabilities, reduce distractions, and facilitate the process of visual perception	 <p>The illustration shows a green-themed AR Cognitive Learning Board for literacy. It features a title 'AR Cognitive Learning Board Literasi' at the top right with a small yellow gear icon. Below the title are three vertical rectangular frames. At the bottom, there are two larger rectangular frames labeled 'Area Letak Kartu' and 'Area Scan Marker'.</p>
2	Image marker	Numeracy	Markers are not designed as simply as 3D object designs in AR, because there must be various patterns to make it easier for the main object to be captured by the camera sensor in the application, thereby increasing scanning accuracy and providing convenience for users.	 <p>The illustration shows three image markers for numeracy. The top row contains two markers: 'Pengenalan Angka' (Number Recognition) featuring a large number '1' on a blue and white geometric pattern, and 'Berhitung' (Counting) featuring a red apple on a blue and white striped pattern. The bottom marker is 'Penjumlahan' (Addition) featuring the equation '1+1=' on a blue and white checkered pattern. Each marker has 'AR Cognitive Learning Board' written at the bottom.</p>

No	Design Component	Sub-Component	Description	Illustration
		Literacy	Markers are not designed as simply as 3D object designs in AR, because there must be various patterns to make it easier for the main object to be captured by the camera sensor in the application, thereby increasing scanning accuracy and providing convenience for users.	
3	3D object Design	Numeracy	The appearance of the object is made simple with the aim of making it easier for students to recognize the object and reduce cognitive load and distractions caused by a design that is too busy.	
		Literacy	The appearance of the object is made simple with the aim of making it easier for students to recognize the object and reduce cognitive load and distractions caused by a design that is too busy.	

No	Design Component	Sub-Component	Description	Illustration
4	Interaction design	Script C# Auto play audio	This C# script contains code used to automatically play audio when a 3D object appears in an AR system	<pre> 1 using System.Collections; 2 using UnityEngine; 3 using UnityEngine.UI; 4 5 public class AutoPlayAudio : MonoBehaviour 6 { 7 private AudioSource audioSource; 8 private bool sudahDiputar = false; 9 10 void Awake() 11 { 12 audioSource = GetComponent<audiosource>(); 13 } 14 15 void OnEnable() 16 { 17 if (!sudahDiputar && audioSource.clip != null) 18 { 19 audioSource.Play(); 20 sudahDiputar = true; 21 } 22 } 23 24 void OnDisable() 25 { 26 sudahDiputar = false; 27 } 28 } </audiosource></pre>
		Script C# Pop-up animation	This C# script contains code used to display a pop-up animation when 3D objects appear on an AR system automatically in turn according to the number of objects on the image marker.	<pre> 1 using System.Collections; 2 using System.Collections.Generic; 3 using UnityEngine; 4 5 public class AppleSpawner : MonoBehaviour 6 { 7 public GameObject[] apples; 8 public float delay = 0.5f; 9 10 private Coroutine currentRoutine; 11 12 public void OnTargetFound(int count) 13 { 14 // stop previous animation if any 15 if (currentRoutine != null) 16 { 17 StopCoroutine(currentRoutine); 18 } 19 20 currentRoutine = StartCoroutine(ShowApplesCoroutine(count)); 21 } 22 23 public void OnTargetLost() 24 { 25 // stop animation 26 if (currentRoutine != null) 27 { 28 StopCoroutine(currentRoutine); 29 currentRoutine = null; 30 } 31 } 32 } </pre>
	Script Real-time feedback	C#	This C# script contains code used to display answer options and feedback in real-time on the AR system.	<pre> 1 using System.Collections; 2 using UnityEngine; 3 using UnityEngine.UI; 4 5 public class ARQuizManager : MonoBehaviour 6 { 7 [Header("UI")] 8 public CanvasGroup choicePanel; 9 public CanvasGroup resultPanel; 10 11 public Button buttons; 12 public Button button; 13 public TMPro.Text resultText; 14 public Image resultIcon; 15 16 [Header("Audio")] 17 public AudioSource audioSource; 18 public AudioClip correctSound; 19 public AudioClip wrongSound; 20 21 [Header("Data")] 22 public int correctAnswer = 2; 23 public int optionA = 2; 24 public int optionB = 3; 25 26 private bool isAnswered = false; 27 private Coroutine currentRoutine; 28 29 // ===== </pre>
5	AR Visualization	Numeracy	The image marker design can be detected well and displays a 3D object in an upright position vertically relative to the surface of the image marker. This display is intended to make the object easier to recognize for students with intellectual disabilities.	

No	Design Component	Sub-Component	Description	Illustration
		Literacy	The image marker design can be detected well and displays a 3D object in an upright position vertically relative to the surface of the image marker. This display is intended to make the object easier to recognize for students with intellectual disabilities.	

4. Implementation of Cognitive Ergonomics in Prototype Design

The prototype design development was carried out through the principles of cognitive ergonomics. The implementation of cognitive ergonomics principles in the prototype design is realized through several features and designs, which can be seen in table 6.

Table 6. Implementation of Cognitive Ergonomics in Prototype Design

No	Cognitive Ergonomics Principle	Design Features and Elements	Objective
1	Perception	<ul style="list-style-type: none"> Concrete objects Soft colors Solid objects without texture Marker-based visualization (image markers as physical cards) Simple pop-up animations 	To help users understand the displayed information/visuals and provide visual stimuli that match user characteristics
2	Attention	<ul style="list-style-type: none"> Marker-based visualization (image markers as physical cards) Supporting audio Minimalist board layout design 	To maintain user focus and reduce distractions by avoiding overly complex visual designs
3	Memory	<ul style="list-style-type: none"> Marker-based visualization (image markers as physical cards) AR visual reinforcement Segmented display 	To support repeated activities, facilitate understanding of concepts, and reinforce learning gradually
4	Response	<ul style="list-style-type: none"> Multiple-choice answer options Real-time system feedback 	To improve user response to the system and reduce error rates

5. Prototype Development Results

The developed prototype is a Cognitive Learning Board learning media based on Augmented Reality. This media is developed for users who are intellectually disabled students at the elementary school level at SLB Paedagogia. The media prototype takes the form of a physical board with cards that are integrated with Augmented Reality technology, making this media semi-digital. The results of the prototype development can be seen in figure 8 to figure 10.



Figure 8. Physical Prototype of Cognitive Learning Board Based on Augmented Reality

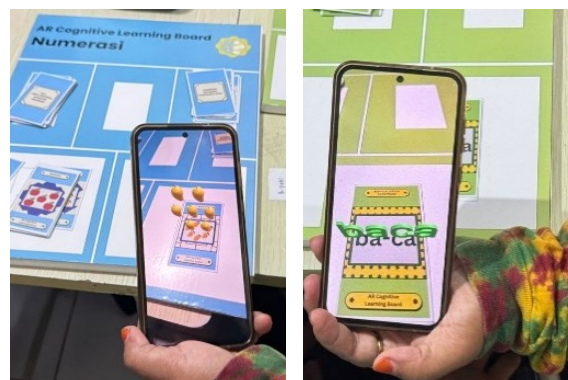


Figure 9. Card Marker Scan Process into 3D AR Object



Figure 10. AR Visualization Results

D. Prototype Testing Results and Design iterations

The delivery stage in the User-Centered Design (UCD) method is conducted through prototype testing with users to evaluate alignment with cognitive ergonomics principles. The testing covers aspects of cognitive load, task performance, and attention, and is supported by usability testing (learnability, efficiency, memorability, error, satisfaction). The initial trial results show that the attention aspect experienced an increase, marked by a longer duration of focus and reduced distractions. However, cognitive load and task performance have not experienced significant changes, particularly in the time to understand instructions, task completion time, and error rate, which tend to remain the same.

Based on these findings, an evaluation and design iteration were carried out, including improvements in audio quality, the addition of audio to the materials, layout adjustments, the use of lowercase letters, and synchronization of animations with the audio. The trial results after the iteration showed that all aspects experienced significant improvements, including reduced completion time, decreased error rate, and increased user focus. A comparison of the previous media observations, prototype trials, and design iterations is presented in table 7 and table 8.

Table 7. Prototype Testing Results and Design Iteration on Numeracy Media

No	Aspect	Indicator	School Media	AR CLB First Design	AR CLB Design Iteration	Interpretation
1	Cognitive Load	Comprehension time	29 Seconds	29 Seconds	20 Seconds	Improved
		Repetition of instructions	3 Times	3 Times	1 Times	Improved
2	Task Performance	Task completion time	2 Minutes	2 Minutes	1 Minutes	Improved
3	Attention	Error rate	60%	60%	20%	Improved
		Focus duration	3 Minutes	4 Minutes	4 Minutes	Improved
		Distraction	4 Times	2 Times	2 Times	Improved

Table 8. Prototype Testing Results and Design Iteration on Literacy Media

No	Aspect	Indicator	School Media	AR CLB First Design	AR CLB Design Iteration	Interpretation
1	Cognitive Load	Comprehension time	29 Seconds	28 Seconds	21 Seconds	Improved
		Repetition of instructions	3 Times	3 Times	2 Times	Improved
2	Task Performance	Task completion time	2 Minutes	2 Minutes	1 Minutes	Improved
		Error rate	60%	60%	40%	Improved
3	Attention	Focus duration	3 Minutes	3 Minutes	4 Minutes	Improved
		Distraction	4 Times	2 Times	2 Times	Improved

Based on the table, these improvements may be explained through the cognitive ergonomics approach applied in the design process. The addition of synchronized audio and animations helped reduce students' cognitive load by presenting information in a more structured and accessible manner, allowing students with intellectual disabilities to process instructions more effectively. Furthermore, the use of lowercase letters and simplified layouts improved readability and minimized confusion, which contributed to lower error rates and faster task completion. Increased focus duration and reduced distractions also indicate that the revised design was more capable of maintaining students' attention during learning activities.

The findings are consistent with previous studies emphasizing that user-centered design and cognitive ergonomics can enhance the usability and effectiveness of learning media for students with special needs. By adapting the interface and interaction design to users' cognitive characteristics, the media becomes easier to understand, more engaging, and more supportive of students' learning processes. Therefore, the iterative design process not only improved usability outcomes but also demonstrated the importance of aligning educational media design with learners' cognitive abilities and limitations.

Conclusion

Based on research results, basic numeracy and literacy learning requires media that can present simple object visualizations, are interactive, and are designed to adjust to students' cognitive characteristics. Learning media also need to be able to reduce cognitive load and increase focus duration so that the learning process becomes more effective. However, the media currently used in schools have not fully been able to accommodate these needs, and thus are not yet optimal in supporting student engagement and understanding in learning. Following up on these findings, this study developed a Cognitive Learning Board media based on Augmented Reality with a cognitive ergonomics approach and the User-Centered Design method through the stages of discovery, definition, development, and delivery. The initial trial results showed that there were still several aspects that needed to be improved, particularly in the design elements and features that affect ease of use and student understanding. Therefore, a design iteration was carried out as a form of product refinement. After going through the iteration process, the test results showed an improvement in the quality of all evaluation aspects. The developed media became more suitable for the needs, abilities, and characteristics of students with intellectual disabilities, and can be used more easily, effectively, and efficiently. Thus, this media has the potential to support the improvement of students' cognitive abilities in the learning process more optimally.

Practically, this study can serve as a reference for teachers, schools, and developers in designing inclusive learning media that are adaptive to the cognitive characteristics of students with intellectual disabilities. The integration of Augmented Reality and cognitive ergonomics can create a more engaging learning environment, improve student participation, and support more interactive learning processes. For future research, broader trials with more participants and diverse educational settings are recommended to evaluate the effectiveness of the developed media. Future studies may also examine the long-term impact on students' learning outcomes and develop more adaptive and personalized features to enhance usability and learning effectiveness.

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