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Development of Augmented Reality (AR)–Based Time Sorting Learning Media for Students with Autism to Understand Day and Night Time Changes

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ABSTRACT

Students with autism often experience difficulties in understanding and organizing time sequences, particularly in distinguishing natural time periods such as day and night. This study aimed to develop Augmented Reality (AR)–based Time Sorting learning media to improve students' understanding of day-night concepts. The research employed a development research approach using the ADDIE model, comprising Analysis, Design, Development, Implementation, and Evaluation. Data were collected through expert validation questionnaires, classroom observations, and pre-test and post-test assessments to evaluate the validity, practicality, and effectiveness of the developed media. The results showed that the AR Time Sorting learning media were categorized as valid and highly feasible, with validity scores of 100% from media and subject matter experts. Teacher responses indicated that the media were easy to use, and students maintained focus on the AR visualizations with minimal distraction. Statistical analysis revealed a significant improvement in students' understanding of day and night concepts, with a significance value of 0.028 ($p < 0.05$). These findings indicate that AR-based Time Sorting learning media are effective in improving students with autism's understanding of day and night concepts.

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1. INTRODUCTION

Children with Autism Spectrum Disorder (ASD) exhibit distinctive characteristics in information processing, communication, and interaction, which significantly affect their learning processes and outcomes. Autism is a developmental disorder that affects verbal and nonverbal communication and social interaction, leading to various cognitive and learning challenges. One critical yet underexplored challenge faced by children with autism is difficulty in understanding temporal concepts, particularly in distinguishing

natural time cycles such as day and night. These difficulties arise not from direct neurological damage, but from impairments in cognitive processing, sensory integration, and conceptual abstraction [3], [9], [10], [18], [21], [30], [15], [23].

Previous studies indicate that children with autism experience persistent difficulties in organizing time sequences and understanding temporal relationships. Children with autism struggle to identify the order and duration of events and to differentiate recurring natural time periods, including day and night. Although day–night transitions are experienced daily, these experiences often fail to form a coherent conceptual understanding due to limitations in abstract reasoning and temporal cognition [1], [2].

This condition is further exacerbated by sensory integration challenges and limited generalization abilities commonly observed in children with autism. Visual cues such as light and darkness are often processed separately from daily routines and auditory information, resulting in fragmented temporal understanding [1]. Moreover, the concept of day and night is inherently abstract, as it is related to the Earth's rotation around the Sun—an astronomical phenomenon that cannot be directly observed. Conventional instructional approaches, therefore, place high demands on spatial imagination and symbolic reasoning, which are particularly challenging for students with autism [19].

In current educational practice, learning media that are specifically designed to accommodate the cognitive characteristics of students with autism in understanding day–night concepts remain limited. Elementary science instruction commonly employs globes and artificial light sources to demonstrate Earth's rotation and its effects. While effective for typically developing learners, these media require abstract visualization and spatial reasoning skills that are often inaccessible to students with autism, leading to suboptimal learning outcomes [8], [27].

This issue is particularly critical in the context of the Kurikulum Merdeka, which mandates that students in Phase A of elementary education recognize natural patterns, such as day-night changes, and relate them to the activities of living beings. These competencies are fundamental and must be achieved by all students, including those with special educational needs. However, the lack of adaptive and inclusive instructional media poses a significant barrier for students with autism in meeting these learning objectives.

Augmented Reality (AR) offers strong potential to address these challenges by transforming abstract concepts into interactive three-dimensional visualizations that can be directly observed and manipulated. AR-based learning media have been shown to enhance attention, reduce distractions, and support concrete, repetitive learning experiences that align well with the learning characteristics of students with autism. Nevertheless, existing AR applications for students with autism predominantly focus on social communication or general learning skills, while AR-based instructional media specifically targeting the understanding of day and night concepts remain scarce [7], [26], [5], [6], [14], [24].

Accordingly, a clear research gap exists in the development of autism-oriented AR learning media that support the comprehension of temporal concepts. This study addresses this gap by developing an AR-based Time Sorting learning media designed to assist students with autism in understanding day and night time changes through structured visual categorization and interactive learning. The contribution of this research lies in providing

an inclusive, curriculum-aligned AR learning solution that supports students with autism's cognitive characteristics and enhances their understanding of fundamental temporal concepts.

2. METHOD

2.1. Research Design

This study employed a Research and Development (R&D) approach, with the primary objective of developing, validating, and evaluating a practical learning product rather than solely generating theoretical findings. The product developed in this study was an Augmented Reality (AR)–based Time Sorting learning media designed to support students with autism in understanding day-night time changes [29].

The development process followed the ADDIE model, which consists of five systematic stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because it provides a structured yet flexible framework that is widely applied in instructional media development research and is suitable for addressing the specific learning needs of students with special educational needs.

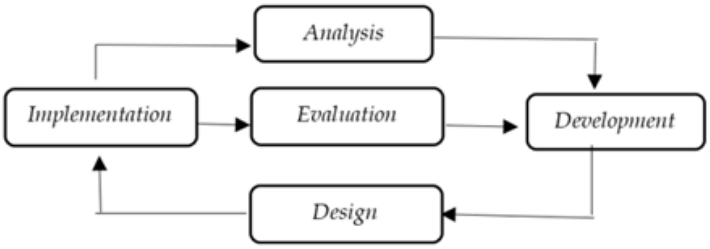

Figure 1. ADDIE Model [29]

2.2. Research Setting and Participants

The study was conducted at Wisdom Academy School in East Surabaya, Indonesia, a school that provides educational services to students with special needs. The research participants consisted of six elementary school students diagnosed with Autism Spectrum Disorder (ASD) in Phase A (Grades 1 and 2).

A purposive sampling technique was used to select the participants. The inclusion criteria were as follows: (1) students had been formally identified as having autism, (2) students were enrolled in Phase A of elementary education, and (3) students demonstrated difficulties in understanding abstract concepts, particularly those related to time, such as day and night changes. This sampling technique was chosen to ensure that the developed media was tested on learners who most required concrete and visual learning support [4], [16], [19], [22].

2.3. Research Instruments

Several instruments were employed to collect data in this study. First, expert validation questionnaires were used to assess the validity and feasibility of the AR-based *Time Sorting* learning media. Media experts and subject matter experts completed these questionnaires. Second, teacher response questionnaires were administered to obtain

teachers' perceptions regarding the usability, practicality, and benefits of the developed media in classroom learning [8].

Third, observation sheets were used to record students' learning behaviors during the implementation stage, including attention focus, enthusiasm, motor responses, and engagement with the AR media. Fourth, pre- and post-tests were administered to measure students' understanding of day and night concepts before and after using the AR *Time Sorting* media.

The expert validation and teacher response questionnaires utilized a four-point Likert scale with the following criteria: 1 = not appropriate, 2 = less appropriate, 3 = appropriate, and 4 = very appropriate. This scale was used to measure attitudes, opinions, and perceptions toward the developed learning media [29].

2.4. Research Procedures

The research procedures were carried out in accordance with the ADDIE model [29]. During the analysis stage, students' learning characteristics, needs, and difficulties in understanding day and night concepts were identified through preliminary classroom observations and teacher interviews.

In the design stage, learning objectives, content structure, activity flow, and interface layouts for the AR-based *Time Sorting* media were designed in accordance with curriculum requirements and students' cognitive characteristics. The development stage involved creating the AR learning media, followed by expert validation to evaluate content accuracy, media design, and instructional suitability.

The implementation stage involved applying the validated AR Time Sorting media to classroom learning activities with the selected students. Students interacted directly with the AR visualizations under teacher guidance. Finally, the evaluation stage was conducted to assess the validity, practicality, and effectiveness of the developed media based on expert feedback, teacher responses, observation results, and learning outcome data [29].

2.5. Data Analysis Techniques

Data analysis was conducted using both quantitative and qualitative methods. Data obtained from expert validation and teacher response questionnaires were analyzed using descriptive quantitative methods, expressed as percentage scores. The percentage was calculated by dividing the total score by the maximum possible score, and the results were interpreted against predetermined feasibility criteria to assess the validity and practicality of the developed media and to guide necessary revisions [29].

Observation data were analyzed using descriptive qualitative methods to identify behavioral patterns related to students' attention, focus, engagement, and initial understanding during the use of the AR Time Sorting media. These findings were narrated to provide a comprehensive account of students' learning experiences.

To evaluate learning effectiveness, pre-test and post-test scores were analyzed using the Wilcoxon Signed Rank Test. This non-parametric statistical test was selected due to the small sample size and the paired nature of the data.

$$Z = \frac{T\left(\frac{1}{4N\,(N+1)}\right)}{\sqrt{\frac{1}{24N\,(N-1)(2N-1)}}}$$

Hypothesis testing was conducted by comparing the significance value (p) with a significance level of 0.05. If $p > 0.05$, the null hypothesis (H_0) was accepted, indicating no significant difference between pre-test and post-test scores. Conversely, if $p < 0.05$, H_0 was rejected, indicating a significant improvement in students' understanding of day and night concepts after using the AR-based Time Sorting learning media.

3. RESULTS AND DISCUSSION

3.1. Research Issues and Questions

This study was conducted to address the following research issues:

a. Whether the AR-based *Time Sorting* learning media are valid and feasible for students with autism.
b. Whether the media is practical and easy to use in classroom learning;
c. Whether the media is effective in improving students' understanding of day and night time changes.

Accordingly, the results are presented to answer these research questions sequentially, followed by a discussion of their implications.

3.2. Results

3.2.1. Development Results of the AR Time Sorting Learning Media

The product developed in this study is an Augmented Reality (AR)–based *Time Sorting* learning media designed to support students with autism in understanding day-night time changes. The media were developed through all stages of the ADDIE model—Analysis, Design, Development, Implementation, and Evaluation—resulting in an Android-based learning application ready for classroom implementation [29].

The AR *Time Sorting* application was designed according to the cognitive and sensory characteristics of students with autism. The application specifications include: (1) Android platform; (2) development software using Unity; (3) application size of approximately 278 MB; (4) usability in both online and offline modes; (5) Indonesian language as the students' first language at Phase A (Grades 1 and 2); (6) printable digital AR markers for flexible use; and (7) a simple interface with interactive 3D objects and minimal visual distractions. These design considerations were intended to reduce cognitive load and support focused learning. The results of the development of the AR Time Sorting learning media application are presented in the following figures, which illustrate its technical, functional, and design aspects.

Figure 2. Menu Selection Screen for Learning Materials

Figure 3. 3D Augmented Reality Display of Daytime Scene

Figure 4. 3D Augmented Reality Display of Night-time Scene

Figure 5. Night-time Activity

3.2.2. Feasibility Results of the AR Time Sorting Learning Media

a. Media Expert Validation

Media expert validation was conducted to evaluate the visual appearance, navigation, and interaction, the suitability of AR technology, and content quality. This indicates that the AR Time Sorting learning media are very suitable for instructional use.

Table 1. Media Expert Validation Results

No.	Aspect	Indicator	Score (1-4)
1	Visual Appearance	Design and color quality	4
		Text/icon readability	4
		Attractive animation/3D objects	4
		Minimal distraction; visuals are not excessive for students with autism	4
2	Navigation and Interaction	Ease of operating the application	4
		Clear usage instructions	4
		AR objects appear stable	4
3	AR Technology Suitability	Features support conceptual learning	4
		3D objects are clearly visible	4
		AR is responsive to the marker	4
4	Content	Appropriateness of content material	4
		Depth of material	4
		Alignment with learning objectives	4
Total Score			52
Feasibility = (Total score obtained / Maximum total score) × 100%= ((52/52) × 100%) = 100%			

Source: BSNP [8]

The results showed a total score of 52 out of 52, corresponding to a feasibility percentage of 100%, placing it in the *highly feasible* category. This result indicates that the visual design, AR responsiveness, and interaction mechanisms are appropriate and well-suited to the learning characteristics of students with autism [25], [26].

b. Subject Matter Expert Validation

Subject matter expert validation focused on content accuracy, presentation, language clarity, and graphical suitability. The evaluation also yielded a total score of 52 out of 52 (100%), categorized as *highly feasible*.

Table 2. Content Expert Validation Results

No.	Aspect	Indicator	Score (1-4)
1	Content Feasibility	The material aligns with Phase A learning outcomes regarding day and night time changes.	4
		The explanation of Earth's rotation and the causes of day and night is scientifically accurate.	4
		The material is appropriate to the cognitive developmental level of Phase A students (concrete and simple).	4
		Examples of daytime and night-time situations are relevant to students' daily life contexts	4
2	Presentation Feasibility	Motivational value and attractiveness of presentation.	4
		Interactivity of the learning media.	4
		Completeness and adequacy of information.	4
3	Language Feasibility	Use of simple and accessible language for students with autism.	4
		Clarity of AR usage instructions	4
4	Graphical Feasibility (Visual Design)	Illustrations and 3D AR objects are attractive, proportional, and conceptually appropriate	4
		The color composition is not excessive and supports the learning focus.	4
		The text is clear, legible, and easily noticeable to students.	4
		The layout is well-organized and systematic.	4
Total Score			52
Feasibility = (Total score obtained / Maximum total score) × 100%= ((52/52) × 100%) = 100%			

Source: BSNP [8]

These results indicate that the learning content aligns with Phase A science learning outcomes, is scientifically accurate, and is presented using simple language and concrete examples appropriate for students with autism. Overall, the expert validation results confirm that the AR *Time Sorting* learning media meet both pedagogical and technical feasibility requirements [25], [26].

c. Practicality Results

The practicality of the AR *Time Sorting* learning media was evaluated through teacher response questionnaires.

Table 3. Practicality Test Results

No.	Aspect	Indicator	Score (1-4)
1	Attractiveness	The application's visual appearance is appealing.	4
		The content is relevant to the learning objectives.	4
		The level of interaction is engaging for students.	4
2	Ease of Use	The application is easy to operate.	4
		The navigation system is simple and intuitive.	4
		The instructions provided are clear and understandable	4
3	Instructional Benefits	The media supports students' conceptual understanding.	4
		The media facilitates visual learning.	4
		The media enhances students' attention and focus during learning activities.	
4	User Appropriateness	The media is aligned with the characteristics of students with autism.	4
		The media can be easily used with teacher or caregiver assistance.	4
Total Score			44
Feasibility = (Total score obtained / Maximum total score) × 100%= ((44/44) × 100%) = 100%			

The results showed a total score of 44 out of 44, corresponding to a practicality percentage of 100%, indicating that the media are *very practical*. Teachers reported that the application is easy to operate, visually engaging, and beneficial for supporting visual learning. In addition, the media were considered suitable for use with teacher assistance, which is essential for students with autism [25], [26].

d. Effectiveness Results

The effectiveness of the AR *Time Sorting* learning media was assessed using pre-test and post-test results from six students with autism. All students demonstrated improved scores after using the media. Statistical analysis using the Wilcoxon Signed Rank Test revealed that all participants showed positive rank differences, with no negative ranks observed.

Table 4. Pre-test and Post-test Results Summary

No.	Student Initial	Pre-test Score	Post-test Score
1	MR	3	5
2	CA	4	6
3	NG	5	6
4	RF	3	5
5	RA	3	4
6	OV	4	6

Table 5. Ranks

Post-Test – Pre-Test	N	Mean Rank	Sum of Ranks
Negative Ranks	0	0,00	0,00
Positive Ranks	6	3,50	21,00
Ties	0		
Total	6		

Table 6. Statistic Test

Statistik	Nilai
Z	-2,201
Asymp. Sig. (2-tailed)	0,028
Exact Sig. (2-tailed)	0,016

The significance value obtained was p = 0.028, which is less than the significance level of 0.05. Therefore, the null hypothesis (H_0) was rejected, indicating a statistically significant improvement in students' understanding of day and night concepts after using the AR Time Sorting learning media [14], [24].

3.3. Discussion

The findings indicate that the AR-based Time Sorting learning media are valid, practical, and effective in supporting students with autism in understanding day and night-time changes. The high feasibility scores from both media and subject matter experts suggest that the combination of simple visual design, interactive AR features, and curriculum-aligned content is appropriate for students with autism, who typically require concrete and structured learning experiences [12], [13], [22], [19].

The practicality results further demonstrate that the media can be easily implemented in classroom settings. Teachers' positive responses indicate that AR-based visualizations help maintain students' attention and reduce distractions, which aligns with

previous studies highlighting the benefits of AR for learners with autism [5], [6], [14], [24], [11], [17].

The effectiveness analysis confirms that AR-based Time Sorting learning media significantly improve students' conceptual understanding of day and night. This improvement can be attributed to the media's ability to transform abstract astronomical concepts into observable and manipulable visual representations. These results support the use of AR as an inclusive learning medium that bridges the gap between curriculum demands and students with autism's learning characteristics.

4. CONCLUSION

Overall, the AR-based Sortir Waktu learning media provide effective support for science learning for students with autism in early grades (Phase A). The media facilitate the understanding of abstract concepts through visual and concrete representations that align with the learning characteristics of students with autism and promote active engagement in the learning process.

This study suggests that AR-based learning media can serve as an alternative instructional approach in inclusive science education, particularly for teaching day and night-time changes. Schools are encouraged to support the integration of technology-based learning media by providing adequate facilities and basic teacher training to optimize their implementation in classroom learning.

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