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AUGMENTED REALITY BOOK DEVELOPMENT FOR ELEMENTARY VISUAL ARTS EDUCATION USING SMARTPHONE-BASED PHOTOGRAMMETRY

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Abstract: *This study develops an Augmented Reality (AR) book to support elementary visual arts learning by enabling intuitive interaction with three-dimensional (3D) forms, scale, and perspective. Using smartphone-based photogrammetry, the book integrates realistic 3D assets for visual exploration beyond two-dimensional (2D) illustrations. The prototype was evaluated through the AREA (Augmented Reality for Enterprise Alliance) heuristic framework to assess usability and functional design. Results show that most interface elements align with heuristic principles, though improvements are needed in navigation, layout, and asset optimization. Overall, the study highlights a set of heuristic insights and preliminary design principles for developing AR-based books: emphasizing multimodal cues, clear spatial orientation, and intuitive object manipulation as key factors to support students' comprehension of artistic 3D objects. The results show that most interface features met heuristic principles, with Evaluator I recording 51.60% "Yes" responses, Evaluator II 35.20%, and Evaluator III 37.97%. The "No" category reached 45.38% for Evaluator II, while "Somewhat" remained low overall, with the highest from Evaluator III (8.10%). Future studies should expand user testing with elementary learners to validate these heuristic guidelines and refine the interactive design framework for broader educational application*

Keywords: *augmented reality, heuristic evaluation, visual arts education, photogrammetry*

Introduction

Learning Basic Visual Arts in elementary schools, particularly for Grade 2 students, involves understanding three-dimensional (3D) forms in artistic objects. 3D artwork is a visual work that has length, width, and height that can be viewed from various angles (Anggun et al., 2024). 3D artwork is important to learn because it fosters student's creativity and aesthetics. Unfortunately second-grade

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elementary students often struggle with three-dimensional concepts. Many student's exam grades are still below standard, with daily test scores not exceeding 75, often ranging from 75 to 55 (Fajrie et al., 2024). Students create artwork based on their imagination, their difficulties are evident in their line drawings that do not follow a 3D structure and rely solely on 3D materials, while underutilizing the dimension of depth (Anggun et al., 2024; Devita et al, 2025; Rahman et al., 2019).

Student's lack of understanding of 3D concepts stems from complex material presented in illustrated textbooks. Current textbooks primarily present 3D shapes through two-dimensional (2D) illustrations, which provide incomplete information about the dimensions and structure of objects. This limitation highlights a learning barrier in understanding 3D objects through conventional illustrations, as students often struggle to perceive spatial depth and structure from static images (Bersier, N. M, 2025). Consequently, learning materials such as 3D-based books can be enhanced with AR Area tools to provide interactive spatial visualization, allowing learners to explore 3D forms directly and reduce the dependency on mental reconstruction. However, the information 3D shapes can only be used effectively when there is fundamental human cognitive level of creativity and logic reasoning (Purnama & Hefira, 2025).

The challenge lies in bridging the gap between 2D representations and students' accurate comprehension of 3D forms. Instructional media should act as a bridge to support students in connecting abstract visual concepts with tangible and realistic experiences. Without this bridge, students may struggle with visualization, memory retention, and manipulation of artistic forms. This calls for innovative media designs that reduce to enhancing students' interactive experiences with art learning materials. Nabil Oktanuryansyah & Anggun Kusumaningtyas (2024) explain that smartphone-based photogrammetry can be applied in designing AR books for elementary school art education. Extending this, Kusumaningtyas & Noviani (2024) demonstrate that interactive AR books can enhance learning engagement and comprehension by enabling students to explore three-dimensional visual information directly, which aligns with the goals of basic visual art education.

In broader context, similar principles have been applied in other domains as well. For instance, Tokopedia's use of augmented reality demonstrates how AR can act as cognitive bridge, by enhancing comprehension by reducing abstract processing and promoting direct interactive engagement (Tirtadarma & Darmo, 2020). Augmented Reality (AR) provides a promising solution, as it overlays physical learning resources with interactive 3D visualizations, allowing students to explore objects more intuitively. Furthermore, AR books have been reported to fulfill essential pedagogical functions, such as drawing attention, facilitating understanding, and compensating for learning difficulties (Elford et al., 2022).

Building on these findings, this study proposes the design of an AR-based book to support students in learning basic 3D forms. The design leverages smartphone-based photogrammetry to create realistic 3D assets, enabling accurate visualization of shape, structure, and texture (Słowiński et al., 2022). This approach reduces unnecessary mental effort by shifting the burden of visualization from imagination to direct interaction with digital content, thereby strengthening students' mental representation of 3D objects (Paas & Sweller, 2012).

This research seeks to answer the following questions:

1. How can AR book features heuristically designed to facilitate intuitive interaction with form, scale, and perspective in visual arts education?

2. What design principles should be recommended for developing AR books—particularly in terms of multimedia principles and interactive 3D visualization—to effectively support elementary students' understanding of artistic 3D objects?

Methodology

This study employed the AREA Heuristic Toolkit (Augmented Reality for Enterprise Alliance). This evaluation is primarily a qualitative method, as it focuses to evaluate the usability of the AR/MR application through heuristic principles, including identifying, describing, and classifying usability problems based on expert judgment. However, the process also incorporates quantitative indicators, such as the frequency of problems, severity ratings, and distribution across heuristic categories, to provide measurable insights into the extent and criticality of the identified issues. Thus, heuristic evaluation can be understood as a qualitative approach supported by quantitative measures. The evaluation conducted by three individual evaluators who identified usability issues that emerged during interaction with the medium. Each finding was documented and grouped according to twelve heuristic categories comprising 109 checklist items. The identified issues were then classified based on the violated heuristics and further analyzed using a severity rating scale. Severity levels were assessed by considering three aspects: the frequency of occurrence, the impact on user experience, and the complexity of the required solution (AREA, 2021).

The collected data were analyzed by calculating the distribution of issues across heuristic categories, the average rating scores, and the identification of data distribution patterns. This analysis provided a comprehensive overview of critical areas requiring attention and served as the foundation for design improvement recommendations. Through this approach, the Augmented Reality Basic Art Guidebook for Elementary School Students was able to identify priority areas for enhancement, ensuring the development of a more intuitive, effective, and user-centered AR/MR learning medium.

Table 1. AREA Heuristic Scale

No.	Item Scale
1	Unboxing & Setting Up
2	Instructions
3	Organization & Simplification
4	Consistency & Flexibility
5	Integration of Physical & Virtual Worlds
6	User Interaction
7	Comfort
8	Feedback to the User
9	Intuitiveness of Virtual Elements
10	Collaboration
11	Privacy
12	Device Maintainability

The design approach of the Augmented Reality (AR) book followed four mainstages: 3D asset generation, refinement, AR integration, and heuristic evaluation.

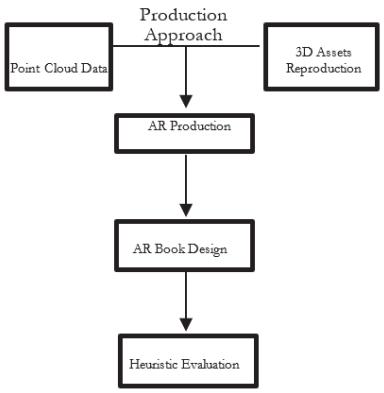

Figure 1. Production Approach

The evaluation process consisted of three steps: (1) testing the AR book through guided interaction, (2) completing a structured questionnaire, and (3) analyzing the questionnaire results to assess the quality of the AR media.

This evaluation provided insights into the effectiveness of the AR book design and its potential as a supplementary learning tool, as well as highlighting areas for future improvement. The final stage focused on evaluating the AR book using a heuristic evaluation method. This was conducted with experts in augmented reality, design, and educational technology, who reviewed the media to identify strengths, limitations, and usability issues (Moran & Gordon, 2023; Nielsen, 2007).

This research subject focuses on the design modeling of an Augmented Reality (AR) supplementary book that develops content from the official Teacher's Guidebook for Visual Arts for Grade 2 elementary school, published by the Indonesian Ministry of Education, Culture, Research, and Technology.

The reference is the section Exploration of 3D Forms (Rizki Raindriati, 2021). The original guidebook introduces clay artworks shaped as plants and animals, as well as handicrafts of Betawi houses made from stick materials. These works are presented through 2D illustrations, examples, and procedural explanations.

Figure 2. Subject Buku Panduan Guru Seni Rupa

The AR book supplements this content by converting the same examples into three-dimensional visualizations using smartphone-based photogrammetry techniques. The learning materials from the guidebook are directly adapted and expanded into a more immersive format. The supplementary AR medium provides realistic representations of form, texture, and spatial depth, enabling learners to observe details that are difficult to convey through flat illustrations.

Result

Assets Creations

At this stage, there are four categories of art objects focusing on the sub–chapter of three-dimensional form introduction, namely: stick house artwork, Betawi-style stick house artwork, clay animal figures, and clay plant figures. These assets were produced using smartphone-based photogrammetry with the following specifications:

Table 2. Exif Metadata

Camera lens	Focal Length	Resolution	Object Distance
Iphone 12 pro–max Rear Camera 12MP, 26 mm lens.	*f* 1.8	226 x 4032	100 mm

A total of 120 photos were captured for each object with a 360° angle coverage to be processed into point cloud format. All the photo data were combined through overlapping to form a three-dimensional pattern. This step served as the initial dataset for the mesh generation stage. The captured photos were processed using Reality Capture software to reconstruct them into point cloud format. This format produces a visual representation consisting of interconnected points, forming objects that include elements such as color, texture, structure, and shape characteristics. The point cloud data also offers flexibility for refinement by selecting and removing irrelevant areas or noise.

The raw data generated consist of four main asset categories: one stick house, one Betawi-style stick house, one clay animal artwork, and one clay plant artwork. All of these assets are cultural objects designed to be displayed through augmented reality media. The transformation of photo data into point cloud resulted in high-resolution assets. Texture and color details were successfully displayed with fidelity close to the original physical objects. The point cloud data were then converted into 3D mesh using Blender 3D software. In this process, the object data were transformed into a triangular mesh, where the geometry of the object is constructed using triangles to create a 3D surface. This format allows direct integration of texture and color into the model, resulting in 3D assets suitable for visualization or further implementation. The following illustrates the results of this reconstruction process.

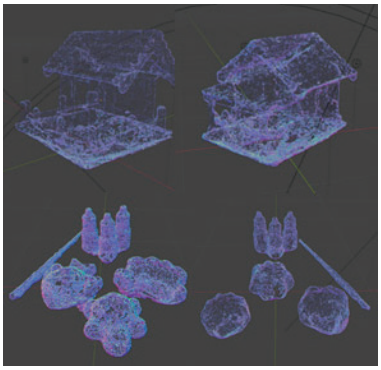

Figure 3. Point Cloud Data Sets

The transformation of photo data into point cloud produced assets with high-resolution quality. Texture and color details were preserved with high accuracy, closely resembling the physical objects. The point cloud data were then converted into 3D mesh using Blender 3D.

The object geometry was represented in triangular mesh format, where the object's form was carefully built to ensure surface continuity. This format enables color and texture mapping directly onto the mesh, producing assets ready for visualization or AR implementation.

Figure 4. Remeshed Data Sets

The resulting models demonstrate well-structured meshes, allowing the geometry of the assets to be displayed in detail. This ensures that shape, texture, and color reflect the physical objects with a high level of realism. Moreover, the 3D assets were optimized in high-poly form to produce smooth resolution.

The 3D materials were designed to replicate the physical characteristics of the objects accurately, incorporating detailed textures and colors using attribute color and the principled BSDF shader. The final visualization achieved proper lighting through the implementation of physically based lighting, enhancing illumination detail and meeting the technical requirements for AR simulation in educational media.

Book Design

The design process begins with creating a conceptualization that organizes sub–chapters or topics. This stage structures the overall layout of the book and serves as an initial guide for arranging pages visually.

Table 3. Book Specification

No.	Book specification	detail
1	Size	315 x 158 mm
2	Total page	32 pages
3	Book cover material	Splendorgel 270 gsm
4	Book content material	Magno Silk 150 gsm
5	Binding	Perfect binding
6	Finishing	Coating doff

The flat plan ensures that content elements, illustrations, and text are arranged according to the learning flow. The book content is derived from the *Art Teacher's Guidebook for Grade 2 Elementary School.*

Figure 5. Book Flat Plan

Each sub–chapter introduces fundamental art concepts adjusted to the developmental stage of students, such as tools, basic shapes, and simple applications. The material progresses gradually from basic concepts to practical activities, including collage making, printmaking, and simple craft exercises. This step-by-step approach aims to build a comprehensive understanding and foster creativity from an early age.

Figure 6. Visual reference

The visual style is tailored for children aged 7–8, the target audience of Grade 2 elementary students learning basic art. The design combines a stylized semi–realistic approach, a warm tone of voice, and playful layouts. Friendly illustrations, supportive messaging, and dynamic compositions help students better engage with the material. The concept is guided

by visual references arranged in a mood-board.

Figure 7. Illustration Assets

The key visual highlights 2D assets of characters and art objects. Soft, warm colors are applied to create a friendly mood and positive perception in learning. The cover design features two characters with an expression of excitement, evoking a joyful impression of exploring basic art.

Figure 8. Key Visual

Brush–stroke effects are used in the background to emphasize an exploratory character, aligned with the art curriculum that emphasizes practice and hands-on exploration. The overall book design is developed in Adobe InDesign, applying a multi–column grid system.

AR Design

The AR development process using Adobe Aero involves several technical stages, including 3D importing, compositing, interaction design, and exporting. The first step is ensuring that the 3D files are in the .glb format, which guarantees compatibility with Adobe Aero. Prior to importing, objects undergo a UV mapping process to maintain visual quality in augmented reality. The unit scale is standardized to centimeters (cm) to ensure accurate dimensions. For example, a clay flower is designed at a height of 5 cm, while a clay fish is modeled with a length of 15 cm.

Table 4. 3D Assets Dimension

AR Assets	Dimension (cm)	Image Target (cm)
House miniature 1	30 x 25 x 10	20 x 20
House miniature 2	30 x 25 x 10	20 x 20
Clay–Fish	15 x 8 x 5	15 x 15
Clay–Turtle	10 x 7 x 5	15 x 15
Clay–Flower	8 x 8 x 5	10 x 15

Once prepared, the objects are imported into Adobe Aero, where they are placed within the main workspace. At this stage, scale adjustments are crucial to achieve realistic proportions. For instance, a miniature house made of ice-cream sticks, measuring 30 cm × 25 cm × 10 cm, must be adjusted to match its real-world dimensions in the AR scene. This ensures proportionality and visual coherence when viewed through AR-supported devices.

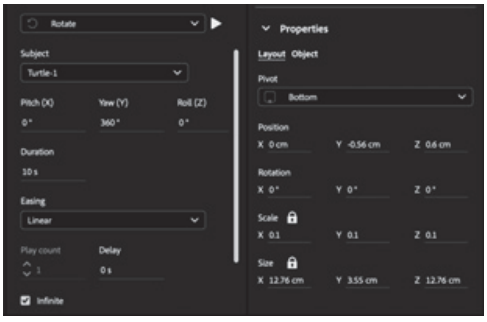

Figure 9. Adobe Aero Presets

The next stage is defining the image target as a reference point for object placement. Each target is designed according to the interaction needs of the user. The house miniature uses an anchor image target measuring 20 cm × 20 cm, while the clay flower, fish, and turtle use image targets of 15 cm × 15 cm. This calibration is essential for objects to appear in the correct position when scanned with an AR device. After placement, interaction behaviors are configured using Adobe Aero's trigger and action features.

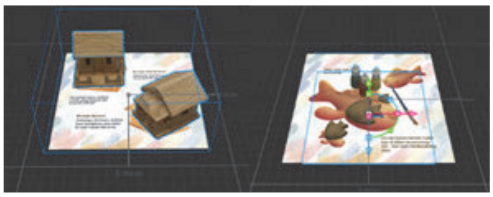

Figure 10. AR Composition

A tap trigger allows users to initiate actions such as rotation and movement by touching the screen. The interaction is designed dynamically to create varied patterns. For example, the clay turtle moves slowly after being tapped, followed by a transformation animation that alters its size. These actions are organized linearly to run in parallel, producing a seamless user experience. Heuristic testing is conducted to ensure that object interactions function as intended and that the displayed dimensions remain consistent with realistic scaling.

The integration of scaling models and image targets represents a connection between digital media (AR) and conventional media (printed book). This hybrid approach enhances both interactivity and learning engagement, bridging tangible and digital experiences.

Discussion

AR Heuristic Tool testing was conducted after the prototype design of the book was completed. This approach was used to assess the usability of an application or system, including in the context of Augmented Reality (AR). The test involved 3–5 respondents who acted as evaluators, each with experience in interface design and user interaction.

Evaluators assessed the strengths and usability of the AR book that had been developed. A total of 12 aspects were evaluated, presented in the validity testing table with a reference value of rTable = 0.878, with N = 3, as follows:

Table 5. Validity Item Scales

No.	Item Scale	Evaluator I *p– corelation*	Evaluator II *p– corelation*	Evaluator III *p– corelation*
1	Unboxing & Setting Up	0.886	0.966	0.887
2	Instruction	0.901	0.901	0.872
3	Organization & Simplification	0.894	0.930	0.897
4	Consistency & Flexibility	0.916	0.896	0.880
5	Integration of Physical & Virtual Worlds	0.895	0.890	0.887
6	User Interaction	0.890	0.930	0.895
7	Comfort	0.896	0.886	0.890
8	Feedback to the User	0.906	0.956	0.884
9	Intuitiveness of Virtual Elements	0.890	0.976	0.963
10	Collaboration	0.910	0.879	0.966
11	Privacy	0.956	0.886	0.855
12	Device Maintainability	0.881	0.896	0.878

All items were declared valid, as the Pearson Correlation values were greater than the rTable (> 0.878) across all items. Based on the validity test results, the validated AR Heuristic Tool questionnaire data was then followed by instrument testing in the form of reliability analysis. The results of the reliability test are presented in the following table:

Table 6. Cronbach Alpha

No	Iteration	*Cronbach alpha* α	Description
1	Evaluator I	0.978	**Valid**
2	Evaluator II	0.993	**Valid**
3	Evaluator III	0.991	**Valid**

Based on the reliability test results, the severity rating data obtained was declared reliable, as the Cronbach's Alpha values were greater than 0.6, namely 0.978 for Evaluator I, 1.019 for Evaluator II, and 1.012 for Evaluator III. Therefore, the data was declared reliable and could be further analyzed based on the AR Heuristic Tool calculations.

AREA Heuristic Tools

Based on the AREA heuristic evaluation data, interpretation was conducted by comparing the distribution of responses across categories: Yes, Somewhat, No, and N/A.

Table 7. AREA Tools Result

Iteration	Yes (%)	Somewhat (%)	No (%)	N/A (%)
Evaluator I	51.60 %	4.40%	31.41 %	12.59 %
Evaluator II	35.20 %	4.40%	45.38 %	15.02 %
Evaluator III	37.97 %	8.10%	33.84 %	20.09 %

Evaluator I recorded the highest percentage of "Yes" responses (51.60%), indicating that more than half of the tested aspects fully met the AREA heuristics.

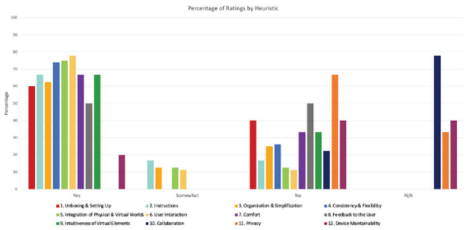

Figure 11. AREA Tools Evaluator I

In contrast, Evaluators II (35.20%) and III (37.97%) presented more moderate assessments, suggesting differing evaluation criteria or interpretations of the heuristic items. The "Somewhat" category remained relatively low overall, with the highest proportion observed in Evaluator III (8.10%).

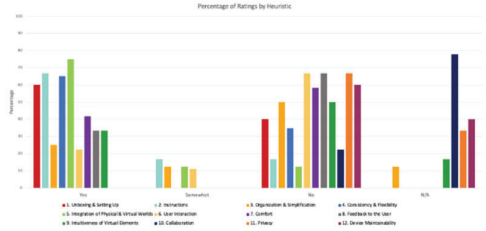

Figure 12. AREA Tools Evaluator II

For the "No" category, Evaluator II reported the highest proportion (45.38%),

demonstrating a more critical stance toward the prototype's compliance with the heuristics compared to Evaluator I (31.41%) and Evaluator III (33.84%). The "N/A" responses were most frequent in Evaluator III (20.09%), followed by Evaluator II (15.02%) and Evaluator I (12.59%), which may indicate differing judgments about the contextual relevance of certain heuristic items.

Overall, the data reveal a noticeable variation among evaluators: Evaluator I tended to emphasize usability strengths, while Evaluator II demonstrated a stricter interpretation of compliance, and Evaluator III reflected a more balanced yet cautious assessment.

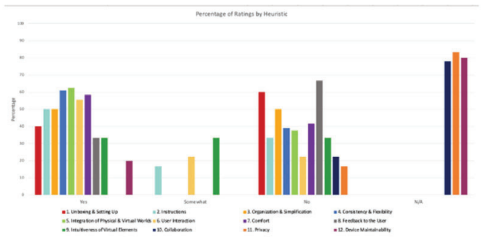

Figure 13. AREA Tools Evaluator III

These variations suggest that the evaluators may have applied different levels of heuristic severity or emphasis an issue commonly identified in heuristic evaluation studies (Nielsen, J1994; Hertzum & Jacobsen, 2001).

Inconsistency does not necessarily invalidate the findings, but it highlights the subjective nature of heuristic assessment, especially when applied to novel media such as AR-based learning tools. Future iterations of this study could improve reliability by refining the AREA heuristics checklist, providing evaluator calibration sessions, and incorporating consensus-based scoring to mitigate interpretive bias.

Conclusion

The heuristic evaluation using the AREA method reveals that the AR book prototype demonstrates strong functional potential in facilitating intuitive interaction with three-dimensional forms, scale, and perspective within elementary visual arts learning. The integration of interactive 3D assets effectively bridges the gap between two-dimensional illustrations and students' spatial understanding by allowing direct manipulation and observation of visual elements.

Findings suggest that most interface components comply with usability and heuristic principles, particularly in clarity of interaction feedback and consistency of spatial visualization. However, several improvements remain necessary, especially in interface layout, navigation flow, and photogrammetry optimization to ensure smoother interaction and better accessibility across diverse classroom devices.

This study recommends several design principles for AR books aimed at elementary school students: 1) displaying 3D shapes with appropriate scales and proportions, 2) needing zoom-in zoom-out interactions for object details, 3) maintaining balanced photogrammetric realism with visual simplicity so that 3D objects are clear, 4) integrating text, narrative, and visuals in a balanced and easy-to-use manner to facilitate children's limited working memory.

Overall, the study highlights a set of heuristic insights and preliminary design principles for developing AR-based books: emphasizing multimodal cues, clear spatial orientation, and intuitive object manipulation as key factors to support students' comprehension of artistic 3D objects. Future studies should expand

user testing with elementary learners to validate these heuristic guidelines and refine the interactive design framework for broader educational application.

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