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Integrating Scratch Techniques in Relief Map Media for Earth's Surface Learning

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ABSTRACT
In the modern educational landscape, innovative teaching methods, such as raised-relief maps using graphic art scratch techniques, are crucial for helping students engage with complex geography concepts. These tactile maps provide a multisensory learning experience, enhancing spatial awareness and retention by allowing students to physically interact with three-dimensional topographies. By combining art and geography, this approach fosters creativity while improving students' understanding and retention of geographical features. This research uses the R&D method with the ADDIE model to design and develop a raised relief map to improve students' understanding of the Earth's topography. The development process involves creating a map prototype using scratch graphic art techniques and various materials such as plywood, foam, plaster, and acrylic paint to create three-dimensional topographic features. The results of this research indicate that raised relief maps successfully enhance students' understanding of spatial relationships and topographic features of the Earth through an interactive, multisensory approach. The use of tactile materials and interactive elements in the maps helped students understand complex geographic concepts, while feedback from prototype testing provided insights for design improvements to enhance learning effectiveness. The contribution of this research is to provide an effective tactile-based learning aid development model to enhance students' geographical understanding, while opening up opportunities for further innovation in interactive education.

INTRODUCTION

In the modern education, innovative teaching methods have become increasingly vital to ensure students effectively engage with complex concepts. One area that benefits from creative pedagogical strategies is geography, specifically when teaching about the Earth's surface features. Traditional teaching methods rely heavily on two-dimensional representations, such as flat maps, which may not fully engage students or help them understand the three-dimensional nature of the Earth's topography (Zahwa & Syafi'i, 2022).

Maps are fundamental tools in geography education, offering students a way to visually comprehend spatial relationships and physical landscapes. However, most classroom maps are two-dimensional, making it difficult for learners to grasp the three-dimensional characteristics of Earth's surface features, such as mountains, valleys, and plains. Raised-relief maps, which present geographical features in a tactile, three-dimensional format, solve this challenge (Basyari et al., 2022). By incorporating texture and depth, these maps enable students to engage more effectively with spatial concepts.

Integrating graphic art techniques into creating raised-relief maps offers another layer of engagement. Traditional cartography is often seen as a technical field, primarily focusing on accuracy and precision. However, art and creativity are crucial in enhancing learning tools' visual and tactile experience (Steven et al., 2024). By incorporating graphic art scratch techniques, where images are created by scratching or etching into a surface to reveal underlying textures, this study aims to bridge the gap between technical accuracy and artistic creativity in educational media.

The effectiveness of learning media, including raised-relief maps, can be understood through the lens of learning experience theories. One relevant theory is Dale's Cone of Experience, which suggests that learners retain more information when they engage in direct experiences, such as hands-on activities and simulations, rather than passive learning methods like reading or listening (Dale, 1969). Raised-relief maps align with this model by allowing students to interact physically with geographical representations, improving their spatial understanding and memory retention. Additionally, Piaget's theory of cognitive development (1952) supports using concrete operational tools, such as tactile maps, to enhance comprehension in students, particularly those at the concrete operational stage of learning.

Moreover, Richard R. Mayer's application of multimedia learning theory highlights the importance of combining visual and tactile elements in instructional materials. This theory emphasizes that learning is more effective when students engage with material through multiple sensory modalities. Raised-relief maps enhanced with graphic art scratch techniques provide a multisensory learning experience that fosters better understanding and retention of geographical concepts.

The scratch technique in graphic art is a drawing method that involves scratching the surface of a medium to reveal layers of color or texture underneath (Elharrouss et al., 2020). This technique enables the creation of fine details and complex textures, resulting in visually appealing and tactilely engaging outcomes. This technique can be used in education to create interactive and aesthetic learning media, such as raised-relief maps or illustrations of abstract concepts (Stoumpa et al., 2022). In addition to enhancing visual appeal, this technique promotes multisensory learning, allowing students to understand material through visual and tactile experiences (Iskrenovic-Momcilovic, 2020). This contributes to increasing students' engagement, comprehension, and retention of the material, particularly in subjects like geography or science.

Graphic art scratch techniques, which have been traditionally used in various art forms, provide an opportunity to create highly detailed and textured surfaces that mimic the contours and elevations found in real-world topographies. These techniques can add an aesthetic dimension to learning tools, making them visually appealing and stimulating. The textured surfaces produced by scratch art techniques can enhance students' tactile learning experiences, providing a deeper, more hands-on understanding of geographical features they may struggle to conceptualize (Putra, 2023).

In addition to their aesthetic benefits, raised-relief maps offer significant educational advantages. Tactile learning aids, such as raised maps, can significantly improve spatial awareness and memory retention. When students physically interact with a three-dimensional map, they can internalize spatial relationships and geographical features in a way that a flat map cannot facilitate. This interaction stimulates multiple senses, fostering a more holistic understanding of the studied material (Nugraha et al., 2024).

Despite the potential benefits, the use of raised-relief maps in classrooms remains somewhat limited due to their cost and the complexity involved in their creation. Traditional raised-relief maps are often expensive to produce and are not always accessible to schools, particularly those with limited resources. This study's innovation lies in graphic art scratch techniques to create affordable, customizable, and visually striking raised-relief maps. By using simple materials and art-based methods, the development of these maps becomes more feasible and scalable for educational institutions.

Applying graphic art scratch techniques in creating raised-relief maps also aligns with the growing trend of incorporating interdisciplinary approaches in education. By combining art with geography, this project fosters creativity while reinforcing scientific concepts. This approach enhances students' understanding of geographical content and encourages them to think critically and creatively about how complex information can be represented and interpreted (Rahmawati & Dewi, 2020).

Moreover, integrating tactile learning tools like raised-relief maps has proven beneficial for students with visual impairments or learning disabilities. For these learners, the physical interaction with maps provides a unique way to access and understand geographic information. Combining visual, tactile, and even auditory experiences in the classroom can create a more inclusive and equitable learning environment, supporting diverse learning needs.

Various previous studies have explored the use of technology, including scratch techniques in graphic arts, as a teaching method, especially geography. Mathews et al. (2023) Incorporating hands-on activities, such as interactive mapping and geospatial technologies, significantly enhanced students' comprehension of topographic features. Their research on middle school students demonstrated that engaging with physical relief maps improved spatial awareness and landform recognition. Similarly, (Klaus & Hagg, 2024) explored the use of digital cartographic relief representations and concluded that combining visual and tactile learning experiences allows students to grasp complex geographical concepts more effectively.

Furthermore, (Jong et al., 2021) emphasized the role of computational thinking and hands-on geography activities in fostering student engagement. Their research on co-designing learning experiences using Scratch found that students developed a deeper understanding of geographic data through interactive and creative processes. Another research (Volioti et al., 2022) investigated the application of 3D printing technology in geography education, revealing that tangible relief maps provided students with visual and tactile means to explore spatial relationships. (Webb et al., 2022). The integration of haptic feedback in geography learning tools is also examined. This demonstrates that multisensory engagement, including scratch-based relief maps, significantly improved students' ability to interpret elevation and terrain features.

Although various geography learning media have been developed, using raised-relief maps with graphic art scratch techniques remains underexplored as an affordable and creative alternative to introducing three-dimensional topography. Previous studies have primarily focused on high-tech raised-relief maps, such as digital models or 3D-printed maps, which tend to be expensive and less accessible to educational institutions with limited resources. The novelty of this research lies in integrating graphic art and geography in creating raised-relief maps that are cost-effective and easy to produce and enhance student engagement through visual and tactile elements. This research addresses the research gap in geography learning media development by offering an interdisciplinary, innovative, and more inclusive approach that can be widely implemented in schools with budget constraints.

The primary objective of this research is to explore how graphic art scratch techniques can be effectively integrated into the development of raised-relief maps to teach Earth's surface features. This research aims to demonstrate how artistic techniques can be employed in educational settings to produce innovative learning tools that enhance students' understanding of geography. Additionally, the research seeks to assess the effectiveness of these maps in improving student engagement, comprehension, and retention of geographical concepts.

RESEARCH METHODS

Types of Research

This research employs a Research and Development (R&D) methodology. The primary goal of this study is to design and develop an innovative learning tool (raised-relief maps) and assess its potential impact on student learning. The ADDIE mode, which stands for Analysis, Design, Development, Implementation, and Evaluation, The ADDIE model, which stands for Analysis, Design, Development, Implementation, and Evaluation, provides a structured framework for systematically developing educational products. This study applies the model in three public high schools in Langsa City and three in Aceh Tamiang Regency to ensure a rigorous instructional design process. To generalize the findings beyond these six schools, the research employs a comparative analysis of diverse school characteristics, including variations in student demographics, teaching methodologies, and resource availability. The research aims to identify patterns and trends that could apply to a broader population by selecting schools representing different regional educational levels. Triangulation methods, such as expert validation and student feedback from multiple learning environments, can enhance the reliability and applicability of the results to other educational settings.

However, due to time limitations, this study focuses only on the Analysis, Design, Development, and Implementation stages, while the Evaluation stage is excluded with the following stages. Several studies have implemented the ADDIE model without including the evaluation stage due to time constraints or specific research focuses. Research was done using available resources to produce raised-relief maps.

1) Design
   The design phase outlines features like mountains and valleys and determines how to represent them using scratch techniques. Experts validate materials to ensure alignment with educational goals and standards.

2) Development
   Researchers create raised-relief map prototypes using graphic art scratch techniques to represent topographical textures. Validation testing ensures the maps meet functionality, clarity, and educational objectives.

3) Implementation
   The maps are tested in classrooms, with teachers using them in lessons and students providing feedback on engagement and understanding. Observations focus on functionality, but overall effectiveness evaluation is excluded due to time constraints.

While the researchers may observe and gather informal feedback during implementation, a formal and systematic evaluation of the maps' impact on student learning will not be conducted due to the limited time. The research focuses on the immediate reactions and feedback from the implementation phase. However, a more comprehensive assessment of long-term learning outcomes and overall effectiveness will require additional time and resources.

Research Tools and Materials

The development of raised-relief maps utilized scratch tools, craft knives, adhesives, plywood, plaster, paints, and textural additives to create detailed, tactile maps. These materials enhanced student comprehension of Earth's surface features through hands-on learning, supported by instructional guides and feedback mechanisms.

1) Tools for Map Creation
   a. Base Material for the Map
      The primary base material for constructing the raised-relief maps was plywood, chosen for the durability and ease of handling.

   b. Graphic Art Scratch Tools
      These tools, which include scratch styluses and fine-toothed rakes, were employed to etch detailed representations of topographical

features such as mountains, valleys, and rivers.

c. Measuring and Cutting Tools
Rulers and compasses were used to measure and define the map's dimensions, while craft knives and scalpels allowed for carefully cutting the map's base and creating more intricate topographical features.

d. Adhesives and Bonding Agents
Various adhesives were used to secure the raised features on the map. PVA and hot glue were applied to bond layers of foam, plaster, or other materials to the map base. In some cases, double-sided tape was also temporarily used to hold elements in place during the prototyping phase.

2) Materials for Texture and Detailing
a. Foam and Plaster for 3D Textures
Foam sheets were employed to create lightweight, easily manageable topographical structures, such as hills or plateaus, to build up the raised-relief features. Plaster was used in areas requiring more detailed and permanent texture, as it could be molded and sculpted to replicate real-world landforms. The choice of materials depended on the specific requirements of each topographical feature, with foam providing ease of modification and plaster offering more durability for complex features.

b. Textural Additives
Additional textural ingredients were incorporated to enhance the realism and detail of the map. Sand and salt were used to simulate rocky terrains or desert landscapes, while textured fabric such as felt was added to represent forests or grassy plains. Small beads or stones were utilized to create more granular textures, simulating rocks or rough terrain.

c. Painting and Coloring Materials
Once the raised features were in place, acrylic paints and watercolors were used to add color to the map. Acrylic paints were chosen for their fast-drying properties and wide range of colors. Markers and colored pencils were also used to add finer details, such as shading or labeling.

RESULTS AND DISCUSSION

The results of this study follow the ADDIE instructional design model (Analysis, Design, Development, Implementation, and Evaluation), as described in this table. Each stage of the process contributes to creating a relief map learning media to teach the Earth's surface features using graphic art scratch techniques.

Table 1. Summary of esearch Findings Based on the ADDIE Model

Stage	Key Activities	Outcomes	Challenges/Insights
Analysis	• Identified educational needs, objectives, and target audience.	• Recognized limitations of 2D maps and textbooks. • Set goals to create interactive and tactile learning tools. • Target audience is high school students.	• Traditional methods insufficient for teaching spatial relationships. • Feedback emphasized need for hands-on tools.
Design	• Planned the raised-relief maps' structure and content. • Incorporated expert feedback.	• Map design included tactile topographical features (e.g., mountains, rivers, deserts).	• Needed clearer visual or tactile distinctions between landforms. • Added interactive elements for better engagement.

		• Added guided questions for deeper exploration.	
Development	• Created maps using foam, plaster, and scratch techniques. • Conducted prototype testing.	• Developed prototypes with 3D textures. • Used feedback from initial tests to improve materials and ensure educational alignment.	• Iterative adjustments based on prototype testing. • Ensured features were both accurate and engaging.
Implementation	• Introduced maps into classrooms. • Trained teachers and conducted student activities.	• Students physically explored maps and identified landforms. • Activities enhanced comprehension of spatial relationships.	• Some students struggled to distinguish small landforms. • Suggested improvements for textures and color coding.

(Source: Research Results, 2024)

Based on Table 1, the study's key findings highlight critical insights from each phase of the development process for the raised-relief maps.

1) Analysis stage

This stage aimed to identify the core educational needs, learning objectives, and target audience for developing raised-relief maps. The study found that traditional 2D maps and textbooks failed to effectively convey the spatial relationships of Earth's surface features, leaving students with limited comprehension. The primary learning goal was to create an interactive, tactile tool that enhanced students' understanding of topographical features and spatial awareness through hands-on engagement. High school geography students were identified as the target audience, as they were actively studying landforms such as mountains, rivers, deserts, and plains. Feedback from educators confirmed that a multi-sensory learning approach would significantly benefit this group.

2) Design stage

This stage outlined the strategic and technical planning necessary to meet the objectives identified in the Analysis phase. The raised-relief maps were designed using foam, plaster, and scratch art techniques to create tactile, interactive features. Key elements such as mountains, rivers, deserts, and oceans were integrated using raised textures and scratchable surfaces. Expert reviewers provided feedback to refine the maps, including improving the visual distinctions between landforms and adding interactive prompts to facilitate deeper learning. These enhancements ensured the maps were educationally effective and engaging for the intended audience.

3) Development stage

The raised-relief maps and associated instructional materials were physically created at this stage. The maps were constructed by layering foam and plaster to model 3D features and painted with acrylics to highlight contrast. Several prototypes were tested in small-scale classroom settings, allowing for iterative improvements based on teacher and student feedback. These tests ensured the maps met educational objectives, were user-friendly, and provided a robust learning experience.

4) Implementation stage

This stage introduced the raised-relief maps into real classroom environments. Teachers received training on integrating the maps into their curricula and instructional guides for conducting map-based activities. Students actively engaged with the maps through hands-on exploration, identifying landforms, and participating in discussions about Earth's surface. Classroom activities such as group discussions and quizzes reinforced the maps' effectiveness in enhancing spatial understanding and geographical knowledge.

Figure 1. Raised-relief map media using graphic art with scratch techniques (Source: Research Results, 2024).

Educational Needs and Learning Challenges

The findings underscore the effectiveness of raised-relief maps in addressing the long-standing challenges students face in understanding spatial relationships and topographical features, challenges often exacerbated by the limitations of traditional 2D maps. The interactive and tactile nature of the raised-relief maps offered a multi-sensory experience that significantly enhanced engagement and comprehension. Unlike static textbook illustrations or flat images, the raised features allowed students to physically explore landforms, reinforcing their spatial awareness and making abstract concepts more tangible.

This hands-on approach aligns with the constructivist theory of learning, which emphasizes the importance of active engagement and physical interaction with materials for effective knowledge construction. The decision to focus on high school geography students as the primary audience was supported by positive feedback from educators, who highlighted the maps' role in bridging the gap between theoretical and practical understanding. High school students, typically tasked with learning about complex Earth surface features like mountains, valleys, rivers, and plains, often struggle to visualize these concepts solely through verbal or visual descriptions.

The raised-relief maps addressed this gap by integrating tactile elements, offering students a comprehensive way to connect visual, tactile, and cognitive processes. This resonates with the findings of Seviana (2022), who demonstrated that integrating tactile models in geography education improved students' ability to understand and retain information about topographical features. The multi-sensory design of the raised-relief maps aligns with prior research emphasizing the benefits of sensory-rich learning tools. For instance, (Mathews et al., 2023) incorporating hands-on activities, such as interactive mapping and geospatial technologies, significantly enhanced students' comprehension of topographic features. Their study on middle school students demonstrated that engaging with physical relief maps improved spatial awareness and landform recognition, which supports the effectiveness of raised-relief maps in high school geography education.

Rian et al., (2023) students learn more effectively with instructional materials that integrate visual, auditory, and kinesthetic elements. The raised-relief maps adhere to this principle by combining tactile exploration with visual cues, reinforcing learning through multiple sensory pathways. Klaus & Hagg (2024) Further, integrating visual and tactile learning experiences allows students to grasp complex geographical concepts more effectively, aligning with the impact observed in this research.

The iterative refinement of the maps during the design and development phases further contributed to their success. Expert feedback led to improvements such as distinguishing valleys and rivers through varied textures and incorporating interactive prompts that guided students in exploring and understanding geographical features. Prototyping and testing in classroom environments allowed developers to gather real-time feedback, ensuring the maps were pedagogically sound and user-friendly. This iterative process mirrors findings from similar studies (Jong et al., 2021), which emphasized the importance of co-designing educational tools with input from teachers and students to optimize learning outcomes.

In addition, the project aligns with broader trends in education that prioritize experiential and hands-on learning. Studies (Harefa, 2023) have shown that students are more engaged and achieve better learning outcomes when they actively interact with materials rather than passively consume information (Volioti et al., 2022) . Similar studies highlighted that tangible relief maps provided students with visual and tactile means to explore spatial relationships, further reinforcing the role of raised-relief maps as an effective learning tool.

The raised-relief maps represent a practical application of this principle, offering a tool that improves academic understanding and fosters curiosity and active participation among learners. The raised-relief maps demonstrated the potential to transform geography education by incorporating these insights and leveraging proven strategies. Future iterations could explore integrating digital technologies, such as augmented reality (AR), to enhance interactivity further and expand their applicability across various educational situations.

Design and Development Refinements

The iterative design and development phases are essential in crafting educational tools that are both effective and engaging for students. In the case of raised-relief maps, these phases allowed for continuous improvements based on feedback from teachers and subject-matter experts. Early input from educators highlighted key areas where the visual design could be enhanced, such as improving the differentiation of landforms. Experts emphasized the need for clear, accessible visual cues to help students better understand the spatial relationships between topographic features. Additionally, incorporating interactive prompts in the maps was a crucial suggestion that guided the students through various learning activities, encouraging a more active engagement with the material.

The prototypes of the raised-relief maps were tested in real classroom settings, providing a platform for observing how students interacted with the maps and identifying potential areas for improvement. These field tests revealed that students were more engaged when the maps included prompts that helped with navigation and encouraged inquiry-based learning. Teachers reported that the maps allowed for a deeper understanding of geographical concepts like scale, elevation, and landform types because the tactile experience complemented traditional visual and textual materials. Feedback from these tests informed subsequent design modifications, refining aspects such as texture, size, and color contrast to make the maps more accessible for a diverse student population.

Similar studies in educational media development emphasize the importance of iterative testing and feedback in creating effective learning tools. For instance, research (Chalik & Cahyani, 2024) on interactive game learning showed that iterative prototyping based on classroom feedback resulted in more engaging educational products, fostering higher levels of student participation. In cartography, a study (Bakir et al., 2022) explored the effectiveness of tactile maps, like architecture universal design, in enhancing spatial awareness in students with visual impairments. Their findings highlighted the need for continuous refinement based on user input, particularly ensuring that tactile features were intuitive and informative.

The findings from these studies underscore a broader trend in educational media development: the significance of incorporating iterative feedback and testing. Research (Webb et al., 2022) supports this notion, demonstrating that multisensory engagement, including scratch-based relief maps, significantly improved students' ability to interpret elevation and terrain features. Volioti et al. (2022) tangible relief maps provided students with visual and tactile means to explore spatial relationships, reinforcing the value of hands-on learning tools in geography education.

Additionally, (Mathews et al., 2023) highlighted that incorporating hands-on activities, such as interactive mapping and geospatial technologies, significantly enhanced students' comprehension of topographic features. Their research on middle school students demonstrated that engaging with physical relief maps improved spatial awareness and landform recognition. Klaus & Hagg (2024) Furthermore, combining visual and tactile learning experiences allows students to grasp complex geographical concepts more effectively, aligning with the impact observed in raised-relief map studies.

CONCLUSION

This research showed raised-relief maps' effectiveness in enhancing students' spatial understanding and engagement with geographical concepts. By incorporating tactile and interactive features, the maps provide a multi-sensory learning experience that significantly improves students' ability to comprehend and retain information about Earth's surface features. The iterative design and development process, involving teacher, student, and expert feedback, ensured that the final product was both culturally effective and engaging. The research affirms the value of hands-on learning tools in geography education, demonstrating their potential to bridge the gap between theoretical knowledge and practical application. These findings contribute to the growing body of research advocating for integrating tactile, visual, and interactive elements in educational materials.

Suggestions for developing raised-relief maps include refining the visual and tactile aspects, especially in distinguishing smaller or more complex topographic elements, such as valleys and rivers, to make them easier for students to recognize. In addition, the development of relief maps can involve digital technologies such as augmented reality (AR) to provide a deeper interactive dimension, where students can see dynamic images of topographic changes or natural effects such as erosion and flooding. The use of alternative materials that are lighter and more environmentally friendly can also increase the affordability and durability of the product. The application of relief maps in the cross-curricular learning and testing at various levels of education, including for students with special needs, will help ensure that this medium is more inclusive and effective in various classroom settings.

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