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AI-INTEGRATED INSTRUCTIONAL VIDEOS TO SUPPORT SPATIAL LITERACY IN GEOMETRY LEARNING ALIGNED WITH SUSTAINABLE DEVELOPMENT GOALS (SDGS) THROUGH SCIENCE AND TECHNOLOGY INNOVATION

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Abstract

This study aimed to develop and evaluate AI-integrated instructional videos for enhancing spatial literacy in geometry learning at the primary school level. Using a design-based research method and the ADDIE model, the instructional videos were equipped with dynamic 3D visualisation and AI-based immediate feedback. The media underwent expert validation and usability testing with students. Results showed high validity in media and content, though language required improvement. The effectiveness was attributed to AI's ability to adaptively scaffold students' spatial reasoning, because it allows dynamic interaction and personalised feedback. This technological innovation aligns with SDG 4, which promotes inclusive and equitable quality education. The study contributes to the advancement of digital learning tools in mathematics education by offering a model that combines science and technology for developing spatial abilities in young learners.

Keywords: Artificial intelligence, Geometry instructional media, Primary education, Science and technology, Spatial literacy.

1. Introduction

Spatial literacy is a foundational component of early mathematics education, particularly in understanding geometric concepts that involve visualising, rotating, and manipulating three-dimensional (3D) objects [1]. These skills (mental rotation, spatial orientation, and spatial visualization) are essential not only for mathematical achievement but also for broader success in Science, Technology, Engineering, and Mathematics (STEM)-related disciplines [2-4]. In the context of elementary education, the introduction of geometric solids such as cubes and cuboids often relies on two-dimensional (2D) representations, which are insufficient for conveying spatial attributes like volume, surface area, and structural relationships [5-7]. Despite its critical role, many students continue to struggle with 3D geometry due to pedagogical limitations in traditional methods that fail to support the development of spatial reasoning [8-11].

In response to these limitations, digital instructional media have emerged to enhance conceptual understanding. Tools such as animations and simulations offer improved engagement but often lack adaptability and responsiveness to students' cognitive needs. Many systems deliver fixed content and minimal feedback, making it difficult to address individual learning gaps or provide dynamic guidance [12]. The integration of artificial intelligence (AI) introduces transformative possibilities for instructional media by enabling real-time feedback, adaptive learning paths, and diagnostic insights into learners' reasoning [13, 14]. AI can enhance spatial literacy by allowing learners to manipulate 3D objects dynamically and receive customised support. However, research in this area has largely prioritised technological development over pedagogical alignment, leaving questions about design validity and user-centred usability unresolved [15, 16].

This study aims to design, validate, and assess the usability of AI-integrated instructional videos for elementary geometry learning, specifically targeting spatial literacy through cubes and cuboids. The novelty of this research lies in combining AI features such as dynamic 3D visualisation and immediate feedback with instructional design principles grounded in educational theory. By aligning these tools with the cognitive development needs of young learners, the study offers a sustainable model for digital learning that supports the sustainable development goals (SDGs) of inclusive and quality education [3, 17]. The findings are expected to contribute both to educational technology development and to classroom practices that foster deeper geometric understanding.

2. Literature Review

Figure 1 presents a series of 2D geometry learning missions that illustrate the use of AI-enhanced instructional media to scaffold basic spatial tasks such as symmetry detection, area recognition, and shape classification. These foundational tasks support the development of spatial literacy by encouraging students to visualise and manipulate geometric forms interactively. Such approaches help learners move beyond rote memorisation and engage more deeply with geometric structures and relationships because they promote logical reasoning through dynamic and adaptive progression based on individual performance levels [18].

Figure 2 illustrat**es** an example of isometric problem-solving tasks, where students are challenged to generate multiple spatially valid configurations of 3D shapes. These exercises develop higher-order spatial skills such as mental rotation and flexible reasoning, which are essential in advanced mathematics and STEM fields. Their inclusion in primary education aligns with curriculum innovations that emphasise three-dimensional visualisation and technical drawing readiness [19]. By integrating these tasks into AI-based systems, instructional media can deliver adaptive scaffolding and real-time feedback, allowing learners to correct misconceptions and build spatial understanding more effectively [3].

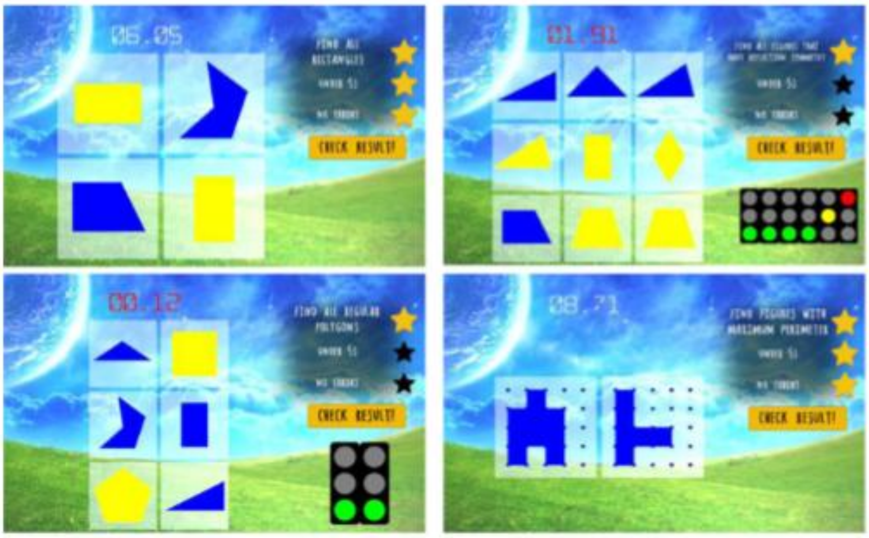

Fig. 1. 2D missions involve identifying forms, symmetry, angles, area, and perimeter from left to right and top to bottom [18].

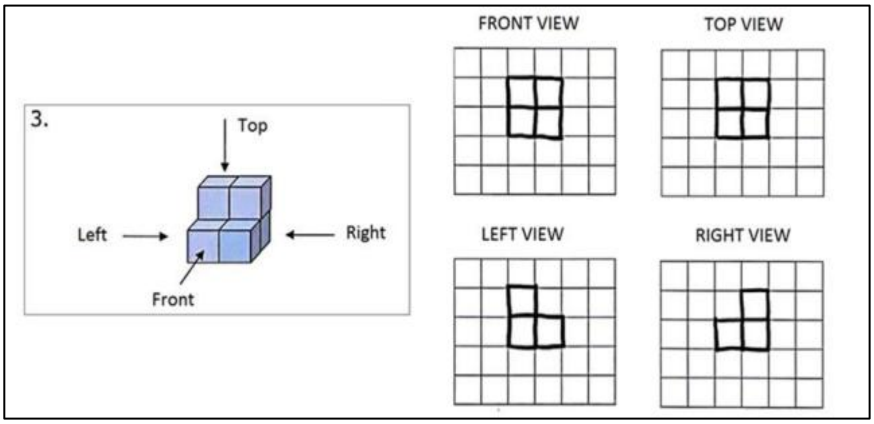

Fig. 2. Two valid isometric solutions and highlighting flexibility in spatial reasoning [19].

AI-based instructional design also enables personalised learning environments through adaptive sequencing and interactive diagnostic tools [20]. Compared to static simulations that provide fixed content, AI-supported systems respond to learner input dynamically, adjusting the complexity of tasks and offering targeted feedback that aligns with learners' spatial development stages [21, 22]. These technologies are grounded in educational design research and supported by learning theories that advocate for responsive, learner-centred instruction in visual-spatial domains [23-25]. The convergence of AI, visualisation technology, and cognitive science offers a compelling framework for developing instructional media that truly addresses students' spatial literacy needs [26, 27].

3. Method

This study employed a research and development approach combined with design-based research, following the ADDIE model stages. Detailed information regarding this method is explained elsewhere [28, 29]. Expert validators in media, geometry, and language evaluated the instructional video. Usability was assessed using a modified System Usability Scale completed by fifth-grade students. Data were analysed using descriptive statistics and percentage calculations to determine validity and practicality [30-36].

4. Results and Discussion

Table 1 displays the results of expert validation, showing very high scores for media and content, but moderate readability. The media expert score of 0.92 confirms strong visual quality supporting mental rotation and spatial orientation. The material expert rated 0.89, affirming the instructional accuracy in delivering geometry concepts aligned with cognitive development in children [2-3]. However, the readability score of 0.49 highlights the need for age-appropriate linguistic refinement to better serve elementary learners [16].

Table 1. Expert validation results.

Validator	Aiken's V	Category	Notes
Media Expert	0.92	Very Valid	High-quality visualisation of spatial objects
Material Expert	0.89	Very Valid	Accurate representation of geometric concepts
Readability	0.49	Valid	Language refinement needed for young learners

Figure 3(a) demonstrates the Dynamic 3D Animation feature, which allows learners to manipulate cubes and cuboids from multiple perspectives. This visual interactivity enables learners to develop a concrete understanding of spatial concepts such as volume and surface area. Unlike static textbook illustrations, AI-enhanced visuals offer exploratory opportunities that deepen mental modelling, which is essential for spatial reasoning [5, 14]. Figure 3(b) shows the AI-Based Immediate Feedback feature, which provides real-time evaluation and adaptive scaffolding. When students input incorrect or incomplete answers, the system responds with tailored feedback and suggestions. This pedagogical responsiveness encourages metacognitive engagement, helping students reflect on their reasoning and improve problem-solving strategies. Such intelligent support bridges gaps in understanding and personalises the learning experience [13, 23].

The integration of dynamic spatial visualisation and responsive AI feedback results in a robust instructional media design. These components not only visualise geometry content but also create interactive environments where students actively construct understanding. The alignment of media features with spatial learning needs validates their relevance in elementary education and supports the realisation of SDG 4 goals in enhancing inclusive, quality digital learning.

Fig. 3. results: (a) scene of dynamic 3D animation feature, and (b) scene of pedagogical responsiveness.

5. Conclusion

This study confirms the high validity and usability of AI-integrated instructional videos in improving spatial literacy. Dynamic 3D animation and adaptive feedback successfully support geometry learning. However, improvements in language clarity are needed to suit younger audiences. This innovation contributes to achieving SDG 4 by promoting equitable access to quality education through science- and technology-driven instructional media.

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