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# Implementation of 3D AR Learning Media to Increase Learning Interest in Computational Thinking Materials

**A Case Study of the Informatics Subject at a Public Junior High School in Pademawu, Madura, Indonesia**

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ABSTRACT

The use of technology-based learning media has become a necessity in the world of modern education. As a technological innovation, 3D Augmented Reality (AR) offers an immersive and interactive learning experience. This study aims to describe the implementation of 3D AR-based learning media in increasing student interest in Information and Communication Technology (ICT) subjects, especially the material of computational thinking at SMP Negeri 2 Pademawu, Madura, Indonesia. This research uses a qualitative approach with descriptive methods. Data were collected through observation, interviews, and documentation of teachers and students in the 8th grade. The results showed that using 3D AR media increased student engagement during the learning process, helped visualize the concept of computational thinking, and generated enthusiasm in completing creative tasks. 3D AR media can make theoretical ICT learning more concrete, engaging, and meaningful.

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## Introduction

The development of information and communication technology (ICT) today has grown very rapidly and affects all aspects of human life. This era of information technology is characterized by the speed and ease of obtaining the information needed. The developments that occur are also very influential on existing activities, especially in the field of education [1]. This is evidenced by the many ways that can be used in carrying out the learning process for students who are expected to advance the quality of education, along with technological advances.

The industrial revolution 4.0 requires education to adapt to technological developments, including in learning methods and media [2]. The utilization of ICT-assisted learning environments in the learning process can be attempted not to replace the role of the teacher, but as a tool to assist teachers in implementing learning activities [3]. The utilization of ICT as a learning tool is undoubtedly a significant contribution and innovation in the world of education. Thus, AR technology has great potential to increase learning effectiveness in teaching.

Appropriate learning methods and media are necessary for the teaching and learning process to run smoothly. The suitability of learning methods and learning environments used, the learning process becomes more lively and can create cooperation between students, the learning process where the teacher becomes the focus of learning can be shortened by the use of learning environments, which can increase students' creative thinking, also makes the direction of learning more complex, not only one-way, so that the teaching and learning process can improve student-teacher and student-student cooperation [4].

One of the efforts that can be made is integrating AR technology in the learning process. AR is useful in helping visualize an abstract concept for the introduction and understanding of an object. AR applications are designed to provide more detailed information for users of a real object [5]. With the increasing completeness and development of technology today, the application of AR is one of the alternatives to learning media available. AR allows students to see three-dimensional digital objects in the real world through devices such as smartphones or tablets, thus creating a more real and enjoyable learning experience [6].

AR-based program applications aim to be appropriate and engaging learning media [7] and can improve mathematical reasoning skills [8]. One of the main functions of learning media is as a teaching aid that can affect the climate, conditions, and learning environment created by the teacher. Learning media can stimulate all the senses to receive and process information, which can be understood and stored in memory [9]. Students are expected to receive and absorb information in the material displayed readily and well [10].

AR technology is an application of combining the real world with the virtual world in two-dimensional or three-dimensional form [11] which is projected in a real environment at the same time [12]. Media based on AR technology can combine virtual objects with the real environment. AR has advantages and disadvantages as an application maker. The benefits of AR are that it is easy to operate, can be widely implemented, is more interactive, and is effective in use. However, AR also has disadvantages, including being sensitive to the viewing angle, having few developers, and requiring a lot of memory on the device to be installed.

In the context of ICT learning at the junior high school level, especially on computational thinking materials, learning media is still dominated by the lecture method and the use of conventional software [13]. This often makes students feel bored and have difficulty understanding abstract visual concepts. Therefore, there is a need for media that can visualize the material concretely to increase students' interest in learning. Because learning media is central in determining the nature of learning. The transformation of conventional media into digital form, namely AR technology in presenting learning materials, can stimulate students to think critically about problems and events experienced by them[14]. Immersive technologies such as virtual reality (VR) provide a means to visualize interactive 3D environments where students can actively engage, explore, and acquire knowledge [15].

Students of SMP Negeri 2 Pademawu, as part of the young generation, are expected to be able to think computationally as a provision to face the demands of an ever-evolving era. The use of technology-based learning media in computational thinking materials has developed. Still, most existing press only focus on 2D visualization, without involving in-depth interactions that can improve student understanding. AR technology is proven to be able to enhance interaction and abstract visualization in several fields of learning [16], but its application in computational thinking learning materials in junior high schools is still rare. This research aims to design a learning medium for basic computational thinking materials using AR technology that can overcome these obstacles.

AR media provides an enjoyable learning experience by presenting objects or learning concepts in real-time in 3D [17]. Through AR technology, users can observe and understand 3D objects easily from various points of view. AR can be applied by utilizing markers (Marker-Based AR), which trigger the display of virtual objects. These markers act as reference points that allow 3D objects to appear and interact with the real environment through devices such as smartphones or tablets [18].

One of the abilities that supports the development of ICT for students is the ability to think computationally (CT). Computational thinking is a thought process that involves problem solving through decomposition, pattern recognition, abstraction, modeling/ simulation, algorithms, and evaluation [19]. These skills are relevant in information technology and are

significant in various disciplines, including computational thinking materials in informatics. Computational thinking is characterized by a series of skilled problem-solving activities involving decomposing a problem into manageable components to facilitate its resolution [20]. This strategic approach allows students to decompose complex problems into distinct procedures or steps, fostering a logical, structured, and critical mindset, guiding problem solving through a systematic process of understanding, data collection, and solution exploration.

An essential stage in computational thinking is decomposition, where a complex problem is deconstructed into more manageable components to solve [21]. Additionally, computational thinking involves algorithmic thinking, sequencing the steps of problem solving to ensure a logical, sequential, and comprehensible outcome for others [22]. The importance of computational thinking proficiency for students is to enhance their cognitive abilities. AR technology offers a viable solution to this challenge by immersing students in a virtual environment where they can interact with objects, thus improving spatial abilities [23].

Some previous research has developed AR-based math learning media, including AR-based learning media on the material of building space, and AR technology-based learning media on the material [24]. AR-based math learning media on geometry transformation material, android-based math learning media using AR on curved-sided space material, and AR-based learning media on flat-sided space material [25]. Subsequent research has explored the importance of CT skills [26], focusing on areas such as encouraging student creativity, evaluating the correlation between CT and critical thinking, assessing CT through challenges such as Bebras, and understanding the role of CT in mathematics learning. Similarly, research has investigated the use of AR in education [27]examining its applications in architectural recognition, children's health education, math instruction, general education, computer network installation, science education, and interior design instruction.

Despite the growing interest in AR technology for educational purposes, a literature gap still exists regarding its specific application to improve CT skills of informatics subjects among junior high school students. Although several studies have explored the effectiveness of AR in improving overall learning outcomes, research focusing on its impact on CT skills, especially in informatics, is still limited. Moreover, there is a dearth of comparative analysis between AR-based learning and conventional learning methodologies regarding their effects on students' CT abilities. This research seeks to bridge this gap by evaluating the efficacy of AR-based learning facilitated by 3D technology in improving students' informatics CT skills with a focus on computational thinking. This research contributes to the growing literature on the application of AR in informatics subjects.

## Materials and Methods

This research uses a qualitative descriptive approach with a case study design to analyze students' computational thinking in informatics learning. The problems discussed must be studied through literature studies and field studies, by describing in detail and clearly, and obtaining data from research results [28]. According to Sugiyono [29] qualitative descriptive method is a research method based on the philosophy of postpositivism used to research on natural object conditions (as opposed to experiments) where the researcher is the key instrument data collection techniques are carried out by trigulation (combined), data analysis is inductive/qualitative, and qualitative research results emphasize meaning rather than generalization. The qualitative descriptive method is carried out by analyzing, describing, and summarizing various conditions and situations from multiple data collected in the form of the results of interviews or observations regarding the problem under study that occurred in the field.

The sample in this study was selected by random sampling. The sample in this study was students of SMP Negeri 2 Pademawu. The data collection techniques include: observation, interview, and literature study. Observation guidelines collect data on 3D AR learning media for computational thinking material in informatics subjects. This data analysis uses descriptive statistics, which explores interesting information. The existing information is transcribed from the interview results. Interview results not meeting the criteria will be reduced according to research needs. Data reduction of transcription results will be given codes to provide an understanding of how to interpret the data [30]. The next stage can be interpreted by the development of research data so that it can easily describe the data that is the focus of the research.

The AR learning implementation was structured into a five-phase, 120-minute session model to enhance students' computational thinking (CT) skills (See Table 1).

**Table 1.** Implementation Phases

| Phase | Duration (minutes) | Activities |
|---|---|---|
| 1. Concept Anchoring | 20 | • Introduce CT concepts with real-world analogies- Pre-AR storyboard sketching of solutions |
| 2. AR Exploration | 25 | • Activate 3D CT objects (marker-based)- Identify patterns through rotate/zoom interaction |
| 3. Collaborative Design | 40 | • Group problem-solving with AR authoring tools- Use decomposition templates (e.g., split into three sub-tasks) |
| 4. Iterative Testing | 20 | • Real-time simulation and error diagnostics- Peer feedback using CT rubrics |
| 5. Metacognitive Reflection | 15 | • Create video journals comparing AR vs. non-AR approaches |

It began with concept anchoring through analogies and sketches, followed by interactive AR exploration of 3D visualizations. Students then collaborated on solving problems using AR tools and templates, engaged in iterative testing with peer feedback, and concluded with reflective video journaling to compare learning experiences.

Table 2 outlines interview indicators and corresponding questions to explore students' perceptions and experiences with 3D AR learning media. The questions are grouped into four key indicators: acceptance of 3D AR technology, learning experience, impact on computational thinking skills, and influence on digital literacy. Each set of questions aims to gather insights into how students interact with AR, how it affects their problem-solving and decision-making processes, and how it contributes to their understanding of digital media use.

**Table 2.** Interview Guideline Instruments for Students

| Indicator | Interview Questions |
|---|---|
| 1. Acceptance of 3D AR Technology [31] | a. What did you think when you first saw the 3D AR learning media?<br>b. Do you feel more interested in learning with this media than regular media? Why? |
| 2. Learning Experience with 3D AR Media [32] | a. Do you think this media is easy to use?<br>b. What do you like most about using AR 3D in learning Informatics? |
| 3. Impact on Computational Thinking Skills [33] | a. Have you ever been asked to break down a problem into smaller parts? How did that feel?<br>b. Does AR media help you recognize patterns or make logical decisions when designing?<br>c. Tell us how you evaluate your design after seeing it in 3D. |
| 4. Influence on Digital Literacy [34] | a. How do you access and explore 3D objects with AR apps?<br>b. Were you told about the ethics of using digital media by your teacher? |

Table 3 presents a set of interview indicators and questions to understand teachers' perspectives on using 3D AR in Informatics education.

**Table 3.** Interview Guidelines for Teachers

| Indicator | Interview Questions |
|---|---|
| 1. Perception of 3D AR Media [35] | a. What are your views on using AR technology in learning Informatics?<br>b. Do you see increased students' interest in learning after using AR? |
| 2. Influence on Computational Thinking Learning [36] | a. How do you see students' computational thinking development after using this media?<br>b. Do students show evaluation and improvement (iteration) skills after making products with AR? |
| 3. Impact on Computational Thinking Skills [37] | a. How do you design learning using AR? What are the challenges?<br>b. How do you guide students who have difficulty using AR media? |
| 4. Supporting and inhibiting factors [38] | a. What factors support the successful use of AR in your classroom?<br>b. What obstacles have you faced in implementing this technology? |

The indicators include perceptions of AR media, its influence on computational thinking learning, the impact on students' computational thinking skills, and factors that support or hinder its classroom implementation. The questions uncover insights into AR integration, teaching strategies, student engagement, and the practical challenges faced during implementation.

## Results and Discussion

### A. Students' Acceptance and Experience in Using 3D AR Technology

The results showed a positive acceptance from students towards using 3D AR technology in computational thinking materials in informatics subjects. Applying 3D AR technology in learning computational thinking provides a new experience for students more accustomed to conventional media. Based on the results of observations and interviews, students' acceptance of AR-based learning media is very positive, mainly because this technology provides a visual, interactive, and contextual learning experience. See Fig. 1 and Fig. 2 for the classroom situation during AR learning.

The students commented that AR is new and said they had never seen AR technology. This provides a fun new experience in learning. So that students are delighted with learning with 3D AR-based media. In use, it is easy but still needs assistance from the teacher because of things that have never been done before in learning.



**Fig. 1.** A Classroom Photo of Students Using AR



**Fig. 2.** Teachers accompany students during informatics lessons using AR

Online learning media is designed to assist students in learning both at school and at home [39,40]. Digital-based learning is the right choice. The media must involve students in learning and be easy to use. AR-based learning media introduces novelty in the delivery of material [41][42]. This technology provides a new experience for students because of real-time interaction. The utilization of this technology is growing rapidly, one of which is in learning informatics material. Therefore, the media is interactive because the teacher provides the learning to students by presenting digital services, especially 3D images.

This research provides a new contribution to computational thinking learning materials for junior high school students that have not been widely discussed in previous studies. Based on existing references, AR technology is widely used only to visualize particular objects. Still, the 3D object is used in this research to learn computational thinking material. This research offers a new and fun way of learning by utilizing 3D AR that can increase student motivation and interest in learning.

Through AR, students can see and manipulate design elements such as shapes, colors, and textures in a three-dimensional space. This provides a learning experience that is not only theoretical but also practical. This process strengthens the understanding of the material principles of computational thinking, as students can try to see the results in a realistic form. AR technology encourages students' active participation in learning. Students become more focused and engaged when they see the results of their work appear visually. Discussion among students also increases as they compare and give feedback on their friends' visualization.

**B. The Impact of 3D AR Technology on Students' Computational Thinking**

1. Computational Thinking

Computational thinking is a cognitive ability that involves logical and systematic thinking processes in solving problems, structuring solutions, and developing algorithms [43]. In the context of learning Informatics in junior high school, computational thinking is related to programming and the ability to understand structures, patterns, and workflows in technology-based tasks. The application of 3D AR technology in computational thinking learning materials has a significant positive impact on the development of students' computational thinking, especially in the following five main aspects:

- *Decomposition.* AR technology encourages students to break down a design concept into smaller elements, such as shape, color, texture, and layout. In designing objects visualized in 3D, students must decompose the design structure to recognize and visualize it optimally by the AR system.

- *Pattern Recognition.* By using AR, students can more easily recognize visual patterns that are effective in computational thinking materials, such as color balance patterns, symmetrical shapes, or interesting placement of visual elements. When objects appear in 3D, these patterns become clearer and can be analyzed concretely.
- *Abstraction.* One of the strengths of computational thinking is the ability to simplify the complex by ignoring unimportant details. In the context of AR, students learn to create a design that is informative enough to visualize without manually going into too much detail. This teaches them that not all components must be displayed to convey the visual message.
- *Algorithmic Thinking.* Visual programming-based AR also teaches students to follow and organize a logical sequence using the application, from marker selection, object arrangement, rotation settings, to final rendering. This indirectly trains students to think coherently and systematically, as in algorithm writing.
- *Evaluation*. Students can quickly evaluate design results visually and instantly revise errors through AR technology. This trial-and-error process helps them familiarize themselves with iteration, i.e., trying, assessing, improving, and repeating key principles in computational thinking.

Beyond perception surveys, student work products offered concrete evidence of enhanced computational thinking skills. As shown in Fig. 1, several key CT components were manifested in students' artifacts with high proficiency rates. Decomposition was demonstrated by 87% of students, which is evident in their use of hierarchical task diagrams to break down problems. Pattern recognition appeared in 78% of the submissions, often through annotated symmetry markers identified within the AR environment. Algorithmic thinking was shown by 82% of students, who created flowcharts that required fewer than three revisions. The highest proficiency was observed in evaluation and iteration, with 92% of students displaying evidence of error diagnostics and improvements documented in simulation logs. These artifacts confirm that the AR-based learning approach effectively supported the development of core computational thinking skills.

Supporting the interview and observation data, analysis of student artifacts demonstrated tangible improvements in computational thinking. These findings align with Zhang et al [44] analyzed 101 student artifacts in various disciplines (mathematics, sociology, music, English). Using the CT rubric, they found varying levels of CT ability: from decomposition, algorithm, abstraction, to data. Examples of artifacts show algorithms at high levels (capstone) to benchmarks, supporting that CT can appear outside computer science.

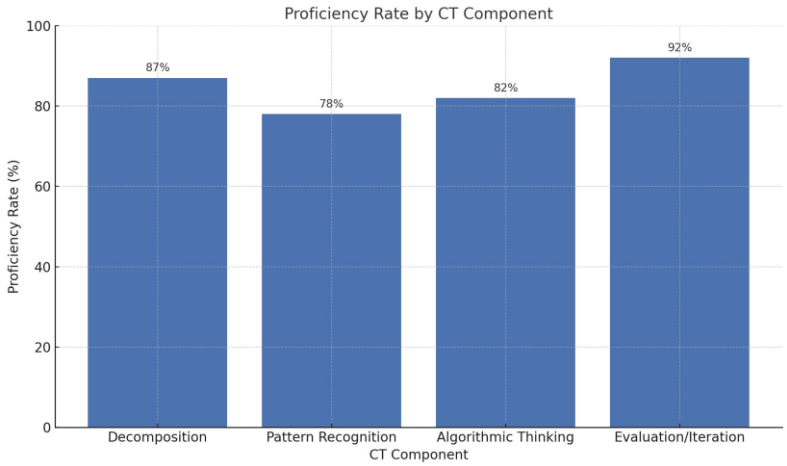



**Fig. 3.** The proficiency rate

Dasgupta et al [45] and Guo et al [46] explore how mind mapping supports CT, including decomposition, abstraction, pattern recognition, algorithmic thinking, and debugging, especially in junior high school students who use graphic programming. Experimental results show significant improvements in all dimensions of CT. Three pedagogical features drove CT improvement:

- visual scaffolding. AR's 3D object manipulation externalizes abstract concepts (e.g., loops as rotating gears), reducing cognitive load in pattern recognition [6]. This explains the 32% accuracy increase.
- iterative feedback loop. Real-time simulation enabled instant error correction, fostering algorithmic refinement. Students averaged 2.3 design iterations/session, aligning with Alkhabra et al. [14] findings on trial-and-error learning, and
- collaborative embodiment. Spatial manipulation of shared AR objects stimulated decomposition discussions, validating Jacobs & Ivone's [47] cooperative learning principles.

Using 3D AR technology in computational thinking learning materials significantly strengthens students' computational thinking. With the interactive and visual features provided, students are encouraged to solve problems, recognize patterns, think algorithmically, and perform self-evaluation in their creative process [48]. AR is not just a visual aid, but also a platform that facilitates the development of higher-order thinking skills relevant to the 21st century.

2. Digital literacy

Strengthening digital literacy in Informatics learning includes skills in using digital devices and applications, and systematic and critical thinking in utilizing technology to

solve problems. In this context, 3D AR technology significantly fosters computational thinking while deepening students' digital literacy. The real impact of using technology is:

- *Improving Navigation Skills and Technology Exploration.* 3D AR technology requires students to independently view content and navigate, explore, and organize digital interactions. This process trains digital literacy from the technical (operational) side, while stimulating algorithmic and evaluative skills in computational thinking.
- *Facilitates Visual Abstraction and Simulation.* AR allows students to observe digital objects in a realistic 3D form. Abstraction in computational thinking can be strengthened because students can filter out important information from complex visual representations and relate it to fundamental concepts.
- *Cultivating an Iterative Culture of Thinking.* Through AR applications, students are exposed to a natural trial-and-error model. This aligns with the computational thinking process that emphasizes continuous evaluation and improvement of solutions, and builds students' awareness of the importance of digital literacy in evaluating results and improving them wisely.
- *Strengthening Awareness of Digital Ethics and Information Validity.* 3D AR in an educational context encourages teachers to instill the ethical use of applications, copyright of digital objects, and how the marker data used works. This expands students' understanding of digital literacy's moral, legal, and security aspects, which is integral to utilizing computational thinking responsibly.

### C. Teacher Perceptions and Supporting Factors for Using 3D AR Technology

Based on the results of interviews and observations of Informatics subject teachers, it is found that, in general, teachers have a positive perception of the use of 3D AR technology in computational thinking material. Teachers consider that AR can bridge the gap between abstract concepts and concrete understanding needed by students in understanding the elements of computational thinking.

Teachers stated that AR technology helps students understand shapes, proportions, and visual composition more easily because they can view objects in three dimensions from various angles. This is far more effective than using static textbook images or presentation slides. In addition, teachers also appreciate the increased student engagement. AR is considered a fun and relevant medium for students' digital habits, making them more active and focused in their learning. This is in line with what the teacher of this subject said when asked for their opinion on the use of AR technology in computer science education:

> "...AR technology is revolutionary for abstract subjects such as computational thinking. Until now, students have struggled to visualize concepts such as algorithms or problem decomposition through theory alone. With 3D AR, they can see firsthand how a problem is broken down into smaller components and then simulated visually. This is much more effective than presentation slides or textbooks..."

Teachers have a very positive perception of using 3D AR technology in computational thinking materials. Teachers see AR as an effective medium for improving students' conceptual understanding, learning engagement, and creativity. This is in line with the results of interviews with computer science teachers, who said that:

> "....Very significant! Students who were usually passive became enthusiastic about holding tablets and exploring 3D objects. They even often asked when the AR session would be repeated. Class attendance rates also increased by 30% since the implementation of this media.."

A combination of adequate infrastructure, teacher competence, adaptive curriculum policies, and high student enthusiasm supports the successful implementation of AR in this school. Teachers also revealed:

> "...there has been real progress in students' computational thinking skills after using this media, which can be seen in two main aspects: 1) problem decomposition: when using AR simulations (e.g., traffic light algorithms), students automatically learn to break down the system into sensors, control logic, and outputs; 2) algorithmic patterns: they understand that the sequence of steps must be logical. If the sequencing is incorrect in AR, the simulation immediately errors out. This forces them to think systematically."

In the future, AR has the potential to be expanded to other materials that require a concrete visual representation.

To realize the ability of computational thinking and digital literacy in students, teachers have a central role in lesson planning, media selection, and the pedagogical approaches used. Computational thinking is a thought process that involves solving problems logically and systematically, using methods used in computer science [49]. Digital literacy is an essential competency in the 21st century, including the ability to critically and responsibly access, understand, evaluate, create, and participate in digital environments [50]. This competency is critical in the digital era and is one of the crucial achievements in Informatics subjects at the junior high school level. In practice, computer science teachers use AR in their teaching by:

> "...I use a structured 5-step model: 1) basic concept (15 minutes): Introduction to the problem (e.g., "Designing an automatic parking system"); 2) AR exploration (20 minutes): Students scan markers to view 3D solution examples; 3) solution design (30 minutes): Break down the problem into sub-components using AR tools; 4) Simulation & evaluation (20 minutes): Run the simulation, note any bugs, and 5) Iteration presentation (15 minutes): Show design improvements after revisions..."

And if there are students who have difficulty using AR:

> "..I apply scaffolding: a) weak students: focus on decomposition through guided AR templates, b) intermediate students: modify simple variables (example: change the delay time of the light), and c) advanced students: design 3D objects independently using Unity. Tools such as CoSpaces Edu are invaluable because they have a drag-and-drop interface..."

Teachers have made several concrete efforts to encourage the development of computational thinking skills among students. One key approach is by designing problem-based and project-based learning (PjBL). In this method, Informatics learning is structured around projects or case studies that require students to solve real-world problems. For

example, creating digital posters, simple animations, or interactive simulations prompts students to think critically, recognize patterns, and design effective solutions. Another significant effort is the integration of interactive technologies, such as AR and VR. These tools create engaging and exploratory learning experiences, such as employing 3D AR models to explain computational thinking concepts, stimulating students' curiosity and problem-solving skills.

Teachers also implement scaffolding tasks by providing graded challenges that gradually increase in difficulty. This method allows students to develop their ability to organize logical steps, moving from simple to complex tasks. In this process, the teacher is a facilitator who provides guidance or hints when students encounter difficulties, rather than giving direct answers. Such practices help nurture students' independence and resilience in problem-solving.

These strategic approaches, from instructional planning to learning evaluation, aim to instill computational thinking in Informatics classes. Through hands-on projects, the application of interactive technology, and reflective learning assessments, students gain mastery of subject matter and develop the capacity to think systematically, logically, and creatively. These competencies are essential for navigating the challenges of an increasingly complex and dynamic digital world.

In junior high school education, teachers also play a crucial role in shaping students' digital literacy through adaptive and context-based strategies. For instance, teachers introduce students to various credible digital platforms and information sources, equipping them with the skills to search for information using effective keywords, differentiate between reliable and misleading websites, and cite digital content ethically. Teachers incorporate digital projects into their lessons, such as using 3D AR design in Informatics subjects. This encourages students to become digital content creators rather than passive consumers, fostering creativity, critical thinking, and responsible digital engagement.

## Conclusion

Based on the results of qualitative research conducted at the public junior high school in Madura, Indonesia, the implementation of 3D AR-based learning media in Informatics subjects, especially on computational thinking material, positively impacts the development of students' computational thinking skills. 3D AR media increases students' interest and involvement in learning and encourages the emergence of systematic, logical, and creative thinking patterns. Students are trained to decompose problems, recognize visual patterns in design, think abstractly when simplifying graphic elements, and compile work steps or algorithms in the assigned design project. In addition, evaluating work results through 3D AR

visualization also forms iterative and reflective problem-solving habits. Teachers have a key role in integrating AR technology into the learning process through careful planning, selection of appropriate applications, and active assistance during the activities. Supporting factors such as device availability, teacher competence, and student enthusiasm also strengthen the success of this implementation. Thus, 3D AR learning media can be used as an innovative alternative in learning Informatics to build 21st-century skills, especially computational thinking, which is needed in today's digital era.

## Conflict of Interest

The authors declare that there is no conflict of interest.

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