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# Redefining Scientific Literacy Through AI-Augmented Contextual Learning for Future-Ready Student

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**Abstract**— *The rapid evolution of Artificial Intelligence (AI) has fundamentally transformed the educational landscape, reshaping how students learn, interact, and construct scientific understanding. In this study, AI-augmented contextual learning is defined as a learning model that integrates artificial intelligence tools—such as adaptive tutoring systems, intelligent simulations, and automated feedback—into real-world contextual science activities to personalize and deepen students' scientific understanding. Using a mixed- methods design, this research examines the impact of this model on students' conceptual understanding, critical reasoning, and inquiry engagement. Quantitative findings show that students in the AI-augmented group achieved a 21.7% higher post-test score (M = 82.4, SD = 6.8) compared with the control group (M = 67.7, SD = 7.5), t(118) = 6.42, p < 0.001. Qualitative analyses reveal improvements in metacognitive awareness, curiosity-driven exploration, and ethical sensitivity in scientific inquiry. These results indicate that AI- augmented contextual learning substantially strengthens scientific literacy by enhancing conceptual mastery, critical reasoning, and inquiry engagement.*

**Keywords**— Scientific Literacy; Artificial Intelligence; Contextual Learning; Digital Pedagogy; Future-Ready Education.
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## 1. Introduction

In the twenty-first century, education faces unprecedented challenges and opportunities driven by the accelerating advancement of Artificial Intelligence (AI). The traditional notion of scientific literacy—once limited to understanding basic principles—has expanded toward competencies such as critical evaluation of information, data-driven reasoning, and ethical scientific application in technologically infused societies [1]. Future literacies now include cognitive flexibility, creativity, and collaboration with intelligent systems.

Contextual learning serves as a pedagogical bridge connecting scientific concepts with students' real-life experiences. This approach emphasizes relevance, inquiry, and active engagement. However, as global education transitions into AI-driven ecosystems, contextual learning must adapt to integrate digital interactivity and personalized feedback loops. AI technologies such as natural language processing, adaptive algorithms, and predictive analytics offer profound possibilities for tailoring learning experiences [2][3].

Despite the integration of digital tools into education, many Indonesian students continue to show low levels of scientific literacy, particularly in data interpretation, reasoning, and inquiry. Traditional contextual learning, although meaningful, often lacks adaptive support to address individual learning needs.

Existing studies highlight AI's potential to enhance conceptual understanding [2][4], but few investigate how AI specifically strengthens contextual learning or redefines scientific literacy within real classroom environments.

Thus, this study aims to: analyze the effect of AI-augmented contextual learning on scientific literacy, and explore students' cognitive and emotional experiences while learning science with AI-based tools.

## 2. Method

This study employed a sequential explanatory mixed-methods design, where quantitative data were collected first to measure learning outcomes, followed by qualitative data to explain and enrich the interpretation.

**Participants**

The sample consisted of 120 secondary school students aged 14–16 years from three public schools in Lombok, Indonesia.

Cluster random sampling was used to assign students into two groups:
- Experimental (AI-augmented contextual learning)
- Control (traditional contextual learning)

**Instruments**
1. Scientific Literacy Test — validated by three experts (Cronbach's α = 0.89).
2. Observation Checklist — measuring engagement, collaboration, and responsiveness.
3. Semi-Structured Interviews — involving 24 students representing both groups.

**Procedures**
Step 1 – Preparation:
Teachers were trained to operate AI simulations and tutoring systems. Instruments were validated, and classes were randomly assigned.

Step 2 – Implementation (6 weeks):
- Week 1: Introduction to contextual problems and AI tools
- Week 2–3: AI-integrated simulations on physics concepts
- Week 4–5: Inquiry projects with continuous AI feedback
- Week 6: Final reflection and consolidation activities

The control group received teacher-led contextual instruction without AI.

Step 3 – Assessment:
Both groups completed post-tests. Observations and interviews were conducted to triangulate data.

**Data Analysis**
Paired-sample t-tests and ANCOVA were used for quantitative analysis. Qualitative data were analyzed with thematic coding [5]. Quantitative data were analyzed using paired-sample t-tests and ANCOVA to assess the significance of mean differences in scientific literacy outcomes. Qualitative data were analyzed through thematic coding (Braun & Clarke, 2021) to identify recurring themes related to motivation, cognitive engagement, and ethical reasoning. Data triangulation ensured consistency across findings and minimized researcher bias.

## 3. Result and Discussion
**Result**
**Quantitative Findings**
Table 1 presents the scientific literacy scores for both groups:

**Table 1.** Mean Scores of Scientific Literacy

| Group | Pre-test (M ± SD) | Post-test (M ± SD) |
|---|---|---|
| AI-Augmented | 58.6 ± 7.1 | 82.4 ± 6.8 |
| Control | 57.9 ± 6.9 | 67.7 ± 7.5 |

The independent t-test revealed a significant difference in post-test scores, $t(118) = 6.42$, $p < 0.001$, indicating strong effectiveness of the model. ANCOVA results showed that the learning model significantly contributed to scientific literacy improvement, $F(1,117) = 21.56$, $p < 0.001$, $\eta^2 = 0.16$.

**Qualitative Findings**
Students in the AI-augmented group expressed increased autonomy and enthusiasm: "AI simulations make it easier for me to test ideas. If I'm wrong, the AI tells me why and what to fix," (S14). Themes emerging from qualitative coding include:
- Heightened metacognitive awareness
- Improved reasoning through real-time feedback
- Increased curiosity-driven inquiry
- More ethical awareness when evaluating scientific claims

**Discussion**
The findings of this study demonstrate that the AI-augmented contextual learning model significantly enhances students' scientific literacy, both quantitatively and qualitatively. The statistically significant difference in post-test scores between the experimental and control groups indicates that integrating artificial intelligence into contextual learning environments provides added pedagogical value beyond traditional instructional approaches.
**Enhancement of Scientific Literacy through AI Personalization**
The substantial improvement in scientific literacy scores among students exposed to AI-augmented contextual learning can be

attributed to the personalized and adaptive nature of AI-based feedback. Unlike conventional contextual learning, where instructional support is largely uniform, AI systems dynamically respond to individual learners' needs by diagnosing misconceptions and offering immediate corrective feedback. This adaptive support accelerates conceptual understanding and promotes deeper cognitive processing [6].

The moderate-to-large effect size ($\eta^2 = 0.16$) further suggests that the learning model itself plays a meaningful role in shaping students' literacy outcomes, rather than improvements being driven by extraneous variables. This finding reinforces the argument that AI functions not merely as a technological supplement but as a pedagogical agent that strengthens learning effectiveness.

**Contextual Learning and Scientific Reasoning Development**

AI-supported simulations and intelligent tutoring systems enabled students to engage more deeply with real-world scientific contexts. Through interactive exploration and manipulation of variables, learners were able to test hypotheses, analyze outcomes, and refine their reasoning processes. These activities align closely with the core dimensions of scientific literacy, particularly evidence-based reasoning and data interpretation [7].

This result supports previous research suggesting that AI-enhanced environments can transform contextual learning into a more dynamic and inquiry-driven process. By embedding AI within authentic scientific problems, students are encouraged to actively construct knowledge rather than passively receive information.

**Metacognitive Awareness and Learner Autonomy**

Qualitative findings revealed notable gains in students' metacognitive awareness. The AI systems provided explanatory feedback that prompted students to reflect on their thinking, identify errors, and adjust learning strategies accordingly. Such reflective practices are critical for fostering self-regulated learning and long-term knowledge retention [8].

These findings corroborate studies indicating that AI-based personalized feedback enhances learners' ability to monitor and control their own learning processes. In science education, this metacognitive dimension is particularly important, as it supports students in navigating complex concepts and evaluating the validity of scientific claims.

**Curiosity-Driven Inquiry and Learning Motivation**

The increased enthusiasm and curiosity reported by students in the experimental group suggest that AI-augmented contextual learning fosters intrinsic motivation. The opportunity to experiment freely within AI-supported simulations reduces fear of failure and encourages exploratory learning. As a result, students become more willing to engage in inquiry, ask questions, and pursue alternative solutions [9].

This motivational aspect distinguishes AI-augmented contextual learning from traditional approaches, where inquiry opportunities may be limited by time constraints and teacher-centered instruction. AI, in this context, serves as a facilitator of sustained engagement and curiosity-driven exploration.

**Ethical Awareness as a Component of Scientific Literacy**

An important qualitative outcome of this study is the emergence of heightened ethical awareness among students. Interaction with AI tools encouraged learners to critically evaluate scientific information, question data sources, and consider the broader implications of technology use in science. This aligns with contemporary views that scientific literacy in the digital era must encompass ethical reasoning and responsible decision-making [10].

By engaging with AI as a learning partner, students developed a more reflective stance toward scientific knowledge, recognizing both its potential benefits and ethical challenges. This dimension is essential for preparing students to participate responsibly in AI-driven societies.

**Theoretical and Practical Implications**

Theoretically, this study contributes to the evolving definition of scientific literacy by positioning human–AI collaboration as a central component of contemporary science education. The findings support frameworks of future-ready education that emphasize adaptability, critical reasoning, and ethical awareness alongside conceptual mastery.

Practically, the results provide empirical evidence for educators and policymakers to integrate AI into contextual science learning in a pedagogically meaningful manner. When thoughtfully designed, AI-augmented learning environments can enhance instructional quality, promote learner autonomy, and cultivate the competencies required for lifelong learning in technologically advanced contexts.

## 4. Conclusion

Quantitatively, the AI-augmented contextual learning model improved students' scientific literacy by 21.7%, with notable gains in conceptual understanding, reasoning, and inquiry engagement. Qualitatively, AI tools increased student autonomy, curiosity, and reflective thinking. These outcomes confirm the study's objective to redefine scientific literacy through the integration of AI-supported learning. The model demonstrates strong potential to cultivate future-ready competencies needed in AI-driven societies. Future research should examine long-term effects, broader cultural contexts, and ethical implications of sustained human–AI collaboration in education.

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