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Development of A Deep Learning Model Based on Augmented Reality to Improve Self-Efficacy and Physics Learning Outcomes of Senior High School Students in Makassar City

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A B S T R A C T

This study aims to develop a deep learning model based on Augmented Reality integrated with Kolb's experiential learning cycle (AR-Kolb) to improve self-efficacy and physics learning outcomes of senior high school students in Makassar. The Research and Development method employing a hybrid approach of Borg and Gall, ADDIE, and Bergman and Moore were applied. The subjects involved 144 eleventh-grade science students from four senior high schools (two public and two private) in Makassar, assigned to experimental and control groups. Instruments included a Bandura-adapted self-efficacy questionnaire, learning outcome tests, expert validation sheets, and observation. Validation results indicated the model was highly valid (average ≥91%). Practicality reached the highly practical category. N-Gain scores for self-efficacy and learning outcomes in the experimental group were in the high category and significantly higher than those of the control group. The maritime-contextual AR-Kolb model proved effective in supporting deep physics learning in Eastern Indonesia.

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INTRODUCTION

Physics learning at the senior high school level in Indonesia, particularly in Makassar City, continues to face challenges related to low conceptual understanding of abstract topics, student self-efficacy, and learning outcomes. Indonesia's science literacy score on PISA 2022 reached only 383 points, far below the OECD average (OECD, 2023). In Makassar, data indicate that physics students' self-efficacy falls into the moderate to low category (mean 3.15 on a 5-point scale), while cognitive learning outcomes remain suboptimal.

Conventional approaches that are one-directional and memorization-based are less capable of facilitating meaningful learning experiences. On the other hand, Augmented Reality (AR) technology has been proven capable of presenting interactive 3D visualizations that help reduce misconceptions and increase student engagement. However, most AR research in Indonesia still focuses on media development rather than on complete instructional models that consciously integrate deep learning frameworks and Bandura's self-efficacy theory.

The novelty of this study lies in the development of a deep learning model based on AR that is fully integrated with David Kolb's experiential learning cycle (AR-Kolb) and contextualized with Makassar's maritime local wisdom (simulations of the pinisi boat, ocean waves, and traditional games). This model is designed to simultaneously improve self-efficacy and physics learning outcomes of senior high school students in Makassar City, while filling the research gap of previous studies that rarely integrated theory with the local context of Eastern Indonesia.

LITERATURE REVIEW

Deep learning emphasizes holistic conceptual understanding, critical reflection, and knowledge transfer, as opposed to surface learning (Marton & Säljö, 1976; Biggs & Tang, 2011; Fullan et al., 2020). In the context of physics, this approach encourages students to analyze, evaluate, and create solutions based on natural laws rather than merely memorizing formulas.

Bandura's self-efficacy theory (1997) states that an individual's belief in their ability influences motivation, persistence, and achievement. The four sources of self-efficacy—mastery experience, vicarious experience, verbal persuasion, and physiological state—can be strengthened through successful and safe learning experiences.

Augmented Reality combines virtual objects with the real environment in real time. Meta-analyses show that AR produces medium to large effect sizes on learning outcomes and motivation in science education (Garzón et al., 2022; Cai et al., 2021). Integrating AR with Kolb's cycle (concrete experience, reflective observation, abstract conceptualization, active experimentation) enables students to experience physics phenomena concretely, reflect, conceptualize, and then experiment actively.

Literature reviews reveal gaps: (1) the scarcity of instructional models (rather than mere media) that explicitly adopt an AR-based deep learning framework; (2) the rarity of simultaneous measurement of self-efficacy and learning outcomes within a single model; and (3) the absence of maritime contextual integration from South Sulawesi. This study addresses these three gaps.

METHODOLOGY

This study employed a Research and Development (R&D) approach using a hybrid model that combines Borg and Gall as the macro framework, ADDIE as the pedagogical framework, and Bergman and Moore as the multimedia production framework. The stages included needs analysis, design, prototype development, expert validation, limited trials, main field testing, operational revision, and product finalization.

The research subjects were 144 eleventh-grade science students from four senior high schools in Makassar City (SMA Negeri 9, SMAS Zion, SMA Negeri 2, and SMA Katolik Rajawali) selected through purposive cluster sampling. The experimental group (72 students) received instruction using the AR-Kolb model, while the control group (72 students) received conventional instruction. A quasi-experimental nonequivalent control group design with a pretest–posttest pattern was used.

Research instruments included: (1) a self-efficacy questionnaire adapted from Bandura's scale (Cronbach's alpha reliability ≥0.87); (2) a physics learning outcome test (Aiken's V validity ≥0.80); (3) expert validation sheets for content, media, and instruction; (4) a practicality questionnaire; and (5) an observation sheet for the implementation of Kolb's cycle. Data were analyzed descriptively for validity and practicality, and using N-Gain, t-test/ANCOVA, and thematic analysis for effectiveness.

RESEARCH RESULT

Expert validation results showed that the AR-Kolb model obtained an average score of ≥91% (highly valid) across content, media, language, and instructional construct aspects. Practicality testing by teachers and students reached the highly practical category (≥89%). Improvements in self-efficacy and learning outcomes are presented in Table 1.

Table 1. Mean Pretest, Posttest, and N-Gain Scores for Self-Efficacy and Learning Outcomes

Variable	Group	Pretest	Posttest	N-Gain	Category
Self-Efficacy	Experimental	3.15	4.28	0.68	High
	Control	3.12	3.48	0.19	Low
Learning Outcomes	Experimental	52.4	84.7	0.68	High
	Control	51.9	66.8	0.31	Moderate

Note: N-Gain high (≥0.70), moderate (0.30–0.69), low (<0.30). Self-efficacy scale 1–5.

ANCOVA results showed significant differences between the experimental and control groups on posttest scores for both self-efficacy and learning outcomes after controlling for pretest scores ($p < 0.001$). Observation of model implementation indicated that all four stages of Kolb's cycle were well executed, and students responded very positively to the maritime-contextual AR simulations.

DISCUSSION

The findings of this study reinforce Bandura's theory that mastery experience obtained through safe and repeatable AR simulations is the primary source of self-efficacy improvement. Students who previously felt "unable" to solve abstract physics problems became more confident after successfully manipulating 3D objects (pinisi boats, ocean waves, force fields) directly.

The significant improvement in learning outcomes aligns with the principles of deep learning and Kolb's experiential learning. The concrete experience stage through AR allowed students to experience physics phenomena concretely; reflective observation encouraged metacognition; abstract conceptualization helped connect experiences with formulas; and active experimentation enabled knowledge transfer to new contexts. This integration produced deeper understanding compared to conventional instruction.

The strength of the AR-Kolb model lies in its local maritime contextualization of Makassar, which makes physics feel relevant to students' lives, as well as its offline design that addresses digital infrastructure limitations in some schools. These findings fill the gap in previous research that tended to develop AR media without a complete instructional model framework and without cultural adaptation to Eastern Indonesia.

CONCLUSIONS AND RECOMMENDATIONS

The deep learning model based on Augmented Reality integrated with Kolb's cycle (AR-Kolb) was declared highly valid, practical, and effective in improving self-efficacy and physics learning outcomes of senior high school students in Makassar City. The four-stage Kolb syntax enriched with maritime-contextual AR simulations successfully created meaningful learning experiences and built students' self-confidence.

It is recommended that physics teachers in senior high schools utilize this model, particularly for abstract topics. The Makassar City Physics Subject Teacher Working Group (MGMP) and the Education Office can adopt the instructional package (offline AR application, teaching modules, student worksheets, and TPACK guidelines) for wider dissemination. Local governments are encouraged to support the provision of simple devices and teacher training so that the model can be replicated in schools with limited infrastructure.

FURTHER STUDY

This study was limited to four senior high schools in Makassar City and focused on certain physics topics. Future research is recommended to expand the sample to more diverse regions of South Sulawesi, test the model's effectiveness on modern physics or thermodynamics topics, and examine long-term impacts on knowledge retention and STEM career interest. Further development could also add multiplayer collaborative features and adaptive feedback based on artificial intelligence.

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