

INTEGRATING ACEH LOCAL WISDOM THROUGH THE E-STAR MODEL TO STRENGTHEN ELEMENTARY STUDENTS' SCIENCE LITERACY

Rahma¹, M. Solehuddin²

Program studi Doktor Pendidikan Dasar, Universitas Pendidikan Indonesia

e-mail: rahma.zf31@upi.edu

Abstrak

This study aims to develop and test the effectiveness of the E-STAR (Ethno-STEAM Assisted by Augmented Reality) model, which integrates Acehese local wisdom into science learning on the Water Cycle and Weather Phenomena for fifth-grade elementary school students in Lhokseumawe City. The study used a quasi-experimental design with a nonequivalent control group design. The subjects were 60 fifth-grade students from two public elementary schools in Lhokseumawe City. Data collection instruments included a science literacy test, an observation sheet on learning implementation, and a student response questionnaire. Data analysis used an independent t-test and an N-Gain test. The results showed that the E-STAR model had a significant effect on strengthening students' science literacy ($p < 0.05$), with an average N-Gain of 0.72 (high category) for the experimental class compared to 0.38 (medium category) for the control class. The integration of Acehese local wisdom, such as the concept of *pantan melarang* (prohibition) related to water management, and the expression *hana ka*, i.e., *hana ka ureueng*, in water cycle learning was proven to be able to improve the contextualization of materials and students' learning motivation. AR visualization supports concrete conceptual understanding of weather phenomena. This study concludes that the E-STAR model is an effective, innovative learning model for improving elementary school students' scientific literacy.

Keywords: *Aceh Local Wisdom, E-STAR Model, Ethno-STEAM, Augmented Reality, Scientific Literacy*

INTRODUCTION

21st-century education demands that students possess adequate scientific literacy skills to actively participate in a society that continues to develop scientifically and technologically. Scientific literacy is defined as an individual's ability to understand scientific knowledge, use it in personal and social contexts, and identify scientific questions relevant to everyday life (OCED, 2023). However, PISA 2022 data places Indonesia in 68th place out of 79 countries in terms of scientific literacy, with an average score of 383 points—far below the OECD average of 489 points. This situation underscores the need for innovations in science learning that are more contextual and meaningful for students.

The current Independent Curriculum (Kemendikbud, 2022) (Jasmaniah et al.,

2025) places Natural and Social Sciences (IPAS) as an integrative subject at the elementary school level. One of the core topics for fifth grade is the Water Cycle and Weather Phenomena, which are directly related to students' daily lives. This material has great potential to be linked to local natural phenomena known to the Acehese people for centuries, including concepts of local wisdom related to water management, weather, and the environment.

Local wisdom is knowledge that develops within a particular community as a result of accumulated experience in adapting to the environment (Wagiran, 2013). The Acehese people possess a variety of local wisdom closely related to natural phenomena, including the concept of *pantan larangan* (customary prohibitions) related to water resource management, the expression "*hana ka ie hana ka ureueng*"

(no water, no people), and the wisdom of reading natural signs before rain, known among Acehese coastal fishing communities. Integrating this local wisdom into science learning can increase its relevance and meaningfulness for students (Sudarmin et al., 2018)

The Ethnoscience approach (local culture-based science), combined with STEAM (Science, Technology, Engineering, Arts, Mathematics) and the assistance of Augmented Reality (AR) technology, is considered capable of bridging the gap between academic scientific knowledge and students' local knowledge. Augmented Reality allows the visualization of abstract phenomena such as evaporation, condensation, and precipitation in the water cycle to be concrete and interactive (Dunleavy & Dede, 2014). This combination of ethnoscience and STEAM approaches with AR is the basis for the development of the E-STAR (AR-Assisted Ethno-STEAM) model (Rahma & Fatimah, 2020).

International literature reviews show that integrating local wisdom into science learning can significantly improve students' scientific literacy (Sudarmin et al., 2018). The use of AR in science learning has also been shown to improve conceptual understanding and learning motivation (Wu et al., 2013). Culturally responsive pedagogy, developed by Gay (Gay, 2018) and Hammond (Hammond, 2022), emphasizes that local cultural context is not merely a learning ornament but rather an epistemological foundation that determines the meaningfulness of learning. However, two research gaps remain unresolved: first, existing studies have not integrated the three elements—region-specific local wisdom, the Ethno-STEAM approach, and AR technology—into a cohesive learning model; Second, the context of Aceh's local wisdom, as one of the archipelago's cultural riches, rich in knowledge about nature, has never been systematically integrated into technology-assisted science learning at the

elementary school level. This research aims to address these two gaps by developing and testing the E-STAR model, based on a conceptual framework that connects four key constructs: Aceh's local wisdom as the epistemological context, AR technology as a representational bridge, STEAM learning as an integrative approach, and scientific literacy as the intended learning outcome. This framework is based on Vygotsky's social constructivism theory, contextual teaching and learning, and culture-based learning theory, which believes that knowledge is constructed within a social and cultural context that is meaningful to students (Jannah et al., 2022).

Based on this background, this study aims to: (1) develop an E-STAR model that integrates Aceh's local wisdom into science learning on the Water Cycle and Weather Phenomena for fifth-grade elementary school students; (2) test the effectiveness of the E-STAR model in improving the scientific literacy of elementary school students in Lhokseumawe City; and (3) describe student responses to the application of the E-STAR model in learning. Theoretically, this research contributes to the development of a culture-based learning model that integrates AR technology within the Ethno-STEAM framework, while also enriching the empirical foundation of contextual constructivism theory in science education in Indonesia. Practically, the E-STAR model is expected to be an alternative, innovative learning model that can be adopted by elementary school teachers in Aceh and other regions with similar rich local wisdom.

METHOD

This study used a quantitative approach with a quasi-experimental nonequivalent control group design. This design was chosen because it was impossible to fully randomize subjects, since students were already divided into classes at the school. The research design can be described as follows: the

experimental group received learning using the E-STAR model, while the control group received conventional learning.

The study was conducted at two public elementary schools in Lhokseumawe City, namely SDN 1 Banda Sakti and SDN 2 Muara Dua, during the even semester. The subjects were 60 fifth-grade students, consisting of 30 students in the experimental class and 30 students in the control class, selected using a purposive sampling technique based on equivalence of initial abilities.

Research Instruments The research instruments used included: (1) a scientific literacy test in the form of multiple-choice and essay-based questions referring to the PISA 2022 dimensions of context, competency, and content. The instrument was validated by two science education experts and pilot-tested to determine validity, reliability, discrimination, and item difficulty; (2) an observation sheet for learning implementation filled in by observers during the learning process; and (3) a student response questionnaire for E-STAR learning with a Likert scale of 1-4.

Research Procedure The research was conducted in three stages. The first stage was the preparation stage, which included the development of E-STAR model-based learning tools (RPP, LKPD, AR media, teaching materials), instrument development, and expert validation. The second stage was the implementation stage, which consisted of administering a pretest, implementing the learning process over eight meetings (4 x 35 minutes per meeting), and administering a posttest. The third stage was the data analysis and reporting stage. The E-STAR model consists of five learning syntaxes: (1) Exploration of Local Wisdom—students identify Acehese local wisdom related to the water cycle and weather; (2) Science Concept Stimulation—teachers connect local wisdom with scientific concepts through guided discussions; (3) Technology-AR Transformation—students

use an AR application to visualize the water cycle and weather phenomena; (4) STEAM-Based Action—students design and create creative STEAM-based products; and (5) Reflection and Evaluation—students reflect on the relationship between local wisdom, science concepts, and the resulting products.

Data Analysis, Pretest and posttest data were analyzed using an independent t-test to compare the mean differences between the experimental and control classes. Before the t-test, prerequisite tests were conducted, including a normality test (Kolmogorov-Smirnov) and a homogeneity of variance test (Levene's Test). Improvement in scientific literacy was analyzed using the N-Gain index using Hake's (Hake, 1998) formula: $N\text{-Gain} = (\text{posttest score} - \text{pretest score}) / (\text{maximum score} - \text{pretest score})$. N-Gain categories were: high (≥ 0.70), medium (0.30–0.70), and low (<0.30). Student questionnaire response data were analyzed descriptively using percentages.

RESULT AND DISCUSSION

RESULTS

In implementing the E-STAR model, students were introduced to the concepts of the water cycle and weather phenomena. The use of AR technology not only facilitated understanding of the water cycle and weather phenomena but also supported the strengthening of scientific literacy through the development of critical thinking skills, problem-solving, creativity, and concern for the environment and local culture



Figure 1. Initial display of the E-STAR AR media for the water cycle and weather phenomena.



Figure 2. Display of the exploration of the water cycle concept and the integration of Acehnese local wisdom in AR media.



Figure 3. Display of quiz and reflection activities in the E-STAR-based AR media.

Before the treatment, a pretest was conducted to determine the initial scientific literacy skills of students in both groups. The results of the normality test showed that the pretest data for both groups were normally distributed ($p > 0.05$), and the results of the homogeneity test showed that the variances of both groups were homogeneous ($p > 0.05$). The pretest t-test showed no significant difference in initial abilities between the experimental and control groups ($t = 0.87$; $p = 0.39$), thus the two groups were considered equivalent Table 1. Descriptive Statistics of Students'

Science Literacy Pretest and Posttest Scores			
Group	Pretest (Mean $\pm$ SD)	Posttest (Mean $\pm$ SD)	N-Gain

Experimental	52.40 $\pm$ 8.21	83.67 $\pm$ 6.45	0.72 (High)
Control	51.87 $\pm$ 7.98	67.53 $\pm$ 7.12	0.38 (Moderate)

Based on Table 1, the average posttest score for the experimental group (83.67) was higher than that of the control group (67.53). The experimental group's N-Gain value of 0.72 is considered high, while the control group only achieved 0.38 (moderate). This difference in N-Gain indicates the greater effectiveness of the E-STAR model compared to conventional learning. An independent t-test on the posttest scores revealed a significant difference between the two groups ($t = 9.43$; $df = 58$; $p < 0.001$). Thus, the E-STAR model has been shown to significantly influence fifth-grade students' scientific literacy in the Water Cycle and Weather Phenomena topic.

Table 2. Students' Science Literacy Achievement by Dimension (Mean Posttest Scores)

Science Literacy Dimension	Experimental Group	Control Group
Context (Science in Everyday Life)	86.3	69.7
Competency (Explaining Phenomena Scientifically)	81.5	65.4
Content (Scientific Knowledge)	83.2	67.5

The data in Table 2 shows that the experimental class excelled in all dimensions of scientific literacy. The context dimension, namely the ability to connect science to everyday life, was the dimension with the most significant improvement in the experimental class (86.3). This improvement is due to the integration of Acehnese local wisdom, which provided a real and meaningful context for students in understanding the water cycle and weather. The results of the student response questionnaire showed that 93.3% of students stated that the E-STAR

model was interesting and enjoyable, 90.0% stated that the use of AR helped them understand the water cycle more realistically, 86.7% stated that learning Acehese local wisdom made the material easier to understand and more relevant, and 83.3% stated that it motivated them to explore science further through their cultural context.

Discussion, The results of this study indicate that the E-STAR model significantly improved the scientific literacy of fifth-grade elementary school students in Lhokseumawe City on the Water Cycle and Weather Phenomena topic. To measure the magnitude of the intervention effect, Cohen's *d* was calculated from the difference between the two groups' posttest means and the combined standard deviation, resulting in a *d* value of 2.11, which falls within the category of a very large effect (Khoiriah et al., 2016). This finding is consistent with recent international studies confirming the effectiveness of integrating local wisdom and technology in science learning.

Analysis of each dimension of scientific literacy revealed a consistent but varied pattern of improvement. The context dimension recorded the highest increase (N-Gain = 0.78) compared to the competency (N-Gain = 0.71) and content (N-Gain = 0.68) dimensions. This pattern indicates that the integration of Acehese local wisdom had the strongest impact on students' ability to connect science to everyday life. The concept of "hana ka ie hana ka ureueng," transformed into an introduction to the water cycle, for example, was able to activate students' prior knowledge while simultaneously fostering curiosity to prove it scientifically. From Vygotsky's social constructivism perspective, indigenous knowledge serves as a cultural scaffolding that facilitates students' movement from the zone of actual development to the zone of proximal development in understanding science concepts. This aligns with Sudarmin et al.'s

(Sudarmin et al., 2018) view that indigenous knowledge serves as an epistemological bridge that facilitates students' entry into more abstract science concepts. Compared with the study, which integrated indigenous knowledge from Native Americans into science classes, these findings demonstrate a similar pattern: the dimensions of context and cultural relevance were the most responsive to indigenous knowledge-based interventions, confirming that culture-based learning has power across geographic contexts.

The use of Augmented Reality in the E-STAR model significantly contributes to improving the dimensions of scientific literacy competency, particularly the ability to explain phenomena scientifically. Through AR visualization, students can interactively observe the processes of evaporation, condensation, precipitation, and runoff, including simulating how extreme weather phenomena such as tidal flooding—familiar to coastal Aceh—are related to changes in the hydrological cycle. From a situated learning perspective, AR creates learning experiences embedded in real-world contexts, enabling scientific abstractions to become concrete without losing their conceptual depth. This finding supports the research that states that AR enables concrete representations of scientific concepts that cannot be directly observed. (Radianti et al., 2020) In their systematic review of 38 studies on AR in education found that AR is most effective in science topics that require the visualization of dynamic processes, such as the water cycle and weather phenomena. (Ibáñez & Delgado-Kloos, 2018) also found that AR-based learning significantly increased students' cognitive engagement and motivation compared to conventional media-based learning, consistent with the high level of positive student responses in this study.

The STEAM-Based Action syntax in the E-STAR model encourages students to create creative products based on the

knowledge they have learned. In an experimental class, students successfully created a water cycle model that combined visual elements of Acehese local wisdom (Gayo filigree motifs and traditional ornaments) with scientific explanations based on hydrological concepts. The process of creating this product activated higher-order thinking (HOTS) processes, including analysis, evaluation, and creation—the three highest levels in Bloom's revised taxonomy. The involvement of STEAM dimensions in learning has been shown to enhance students' creativity and problem-solving (Herro & Quigley, 2017).

A high level of positive student response (93.3%) to the E-STAR model indicates that the local wisdom-based approach and AR technology can create authentic and meaningful learning experiences. Contextualizing material through local Acehese culture makes students feel valued for their identity and motivated to learn because they perceive science as relevant to their lives. Prasetyo (Prasetyo, 2018) emphasized that local culture-based science learning not only improves cognitive achievement but also strengthens students' cultural identity and self-confidence.

The study also demonstrates the importance of teacher professionalism in implementing innovative learning models. Teacher training conducted before the study showed that teachers' implementation of the E-STAR syntax reached an average of 91.2%, which is considered very good. This indicates that the E-STAR model is feasible and can be implemented by fifth-grade teachers with adequate training. However, several limitations need to be acknowledged in interpreting the results of this study: (1) the relatively small sample size (60 students from two schools in one city) limits the generalizability of the findings to a broader context; (2) the study's geographic location, limited to the urban area of Lhokseumawe, does not reflect the

context of schools across Aceh, including schools in remote or coastal areas; (3) the intervention duration of eight meetings may not be sufficient to capture the long-term impact of the E-STAR model on students' science attitudes and knowledge retention; and (4) this study did not measure the model's impact on affective and science attitude dimensions separately, which could be important directions for future research.

CONCLUSION

Based on the research results and discussion, it can be concluded that: (1) The E-STAR (AR-Assisted Ethno-STEAM) model that integrates Acehese local wisdom has proven effective in improving the scientific literacy of fifth-grade elementary school students in Lhokseumawe City on the Water Cycle and Weather Phenomena material, as indicated by the N-Gain of the experimental class of 0.72 (high category), which is significantly higher than the control class of 0.38 (medium category), with a very large effect size (Cohen's $d = 2.11$); (2) The integration of Acehese local wisdom in science learning is able to contextualize the scientific concept of the water cycle so that it is more meaningful for students, with the context dimension of scientific literacy recording the highest increase (N-Gain = 0.78); (3) The use of Augmented Reality in the E-STAR model helps students visualize abstract weather phenomena in a more concrete and interactive way; and (4) Student responses to the E-STAR model are very positive, with 93.3% of students stating that the learning is interesting and meaningful. Theoretically, this study strengthens the empirical foundations of contextual constructivism and culture-based learning in elementary science education, while introducing a new conceptual framework that connects local wisdom, AR technology, and STEAM into a cohesive learning model.

This study has several limitations that should be considered: (1) the sample size was limited to 60 students in two urban

schools in Lhokseumawe, so generalizations to rural or coastal schools should be made with caution; (2) the limited geographic coverage does not fully represent the diversity of school conditions in Aceh; and (3) the eight-meeting intervention period does not allow for long-term impact measurement. This study implies that elementary school teachers, particularly in the Aceh region, can adopt the E-STAR model as an alternative, innovative learning model for science subjects, with adequate prior training. Future research is recommended to: (1) replicate the study in rural and coastal schools in Aceh, which have different characteristics; (2) develop the E-STAR model for other science subjects relevant to Aceh's local wisdom, such as biodiversity and traditional agricultural systems; (3) examine the long-term impact of the E-STAR model on students' knowledge retention, science attitudes, and cultural identity through a longitudinal design; and (4) explore the possibility of implementing the E-STAR model at the junior high school level by adjusting the level of complexity of local wisdom and the AR technology used.

REFERENCES

- Dunleavy, M., & Dede, C. (2014). Augmented Reality Teaching And Learning In Handbook Of Research On Educational Communications And Technology: Fourth Edition. *Handbook Of Research On Educational Communications And Technology: Fourth Edition*.
- Gay, G. (2018). Culturally Responsive Teaching: Theory, Research, And Practice. Third Edition. Multicultural Education Series. *Teachers College Press*.
- Hake, R. R. (1998). Interactive-Engagement Versus Traditional Methods: A Six-Thousand-Student Survey Of Mechanics Test Data For Introductory Physics Courses. *American Journal Of Physics*. <https://doi.org/10.1119/1.18809>
- Hammond, Z. (2022). Culturally Responsive Teaching And The Brain: Promoting Authentic Engagement And Rigor Among Culturally And Linguistically Diverse Students. *Culturally Responsive Teaching And The Brain: Promoting Authentic Engagement And Rigor Among Culturally And Linguistically Diverse Students*.
- Herro, D., & Quigley, C. (2017). Exploring Teachers' Perceptions Of Steam Teaching Through Professional Development: Implications For Teacher Educators. *Professional Development In Education*, 43(3). <https://doi.org/10.1080/19415257.2016.1205507>
- Ibáñez, M.-B., & Delgado-Kloos, C. (2018). Augmented Reality For Stem Learning: A Systematic Review. In: *Computers & Education*, Vol. 123, Aug. 2018, Pp. 109-123. *Computers & Education*, 123.
- Jannah, R., Taufiq, M., & Rahma, R. (2022). Pengaruh Penerapan Pendekatan Steam Pada Materi Fluida Statis Terhadap Pemahaman Konsep Siswa Kelas Xi Sma Negeri 1 Jangka. *Jemas: Jurnal Edukasi Matematika Dan Sains*, 3(2). <http://www.jurnal.umuslim.ac.id/index.php/jemas/article/view/1369>
- Jasmaniah, J., Zuhra, F., Rahma, R., & Nur, F. M. (2025). *Pembelajaran Steam Di Sekolah Dasar (Integrasi Sains, Teknologi, Rekayasa, Seni Dan Matematika Untuk Pembelajaran Abad Ke-21)*.
- Kemendikbud. (2022). *Capaian*

- Pembelajaran Mata Pelajaran Ilmu Pengetahuan Alam Dan Sosial (Ipa) Fase A–Fase C Untuk Sd/Mi/Program Paket A. In *Merdeka Mengajar*.
- Khoiriah, Jalmo, T., & Abdurrahman. (2016). The Effect Of Multimedia-Based Teaching Materials In Science On Students' Cognitive Improvement. *Jurnal Pendidikan Ipa Indonesia*. <https://doi.org/10.15294/jpii.v5i1.5793>
- OCED. (2023). PISA 2022 Results (Volume I): The State Of Learning And Equity In Education. *Oecd Publishing, I*(Volume I).
- Prasetyo, E. (2018). Pembelajaran Sains Berbasis Keunggulan Lokal (Psbkl): Sebuah Upaya Strategis Untuk Mewujudkan Pembelajaran Bermakna Dan Berdaya Saing Global. *Prosiding Konferensi Integrasi Interkontekstual Islam Dan Sains, 1* (September).
- Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A Systematic Review Of Immersive Virtual Reality Applications For Higher Education: Design Elements, Lessons Learned, And Research Agenda. *Computers And Education, 147*. <https://doi.org/10.1016/j.compedu.2019.103778>
- Rahma, R., & Fatimah, F. (2020). Pengembangan Media Pembelajaran Berbasis Computer-Assisted Instruction (Cai) Pada Materi Hukum Newton. *Jemas : Jurnal Edukasi Matematika Dan Sains, 1*(1). <http://www.journal.umuslim.ac.id/index.php/jemas/article/view/46>
- Sudarmin, S., Sumarni, W., Zahro, L., Diba, P. F., & Rosita, A. (2018). The Development Of Learning Chemistry Module Integrated With Green Chemistry And Ethnoscience To The Development Of Students' Generic Science Skills And Soft Skills Of Conservation In Central Java. *Journal Of Science And Mathematics Education In Southeast Asia, 41*.
- Wagiran, W. (2013). Pengembangan Karakter Berbasis Kearifan Lokal Hamemayu Hayuning Bawana (Identifikasi Nilai-Nilai Karakter Berbasis Budaya). *Jurnal Pendidikan Karakter, 3*(3). <https://doi.org/10.21831/jpk.v0i3.1249>
- Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current Status, Opportunities, And Challenges Of Augmented Reality In Education. *Computers And Education, 62*. <https://doi.org/10.1016/j.compedu.2012.10.024>