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Integrating Sipakatau cultural values into augmented reality assisted STEAM learning to enhance students' learning independence

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Abstract: This study aimed to examine the effectiveness of Science, Technology, Engineering, Arts, and Mathematics (STEAM) learning supported by Augmented Reality (AR) and integrated with the local cultural value of *Sipakatau* in improving primary school students' learning independence. A quantitative quasi-experimental approach employing a pretest–posttest nonequivalent control group design was conducted at SDN 24 Kalibone, Pangkep Regency, Indonesia. Using total sampling, 72 sixth-grade students participated, comprising 33 students in the experimental group and 39 in the control group. The experimental group received four STEAM learning sessions integrating AR and *Sipakatau*, while the control group received conventional instruction. Data were collected using a 24-item learning independence questionnaire and analyzed through descriptive statistics, normalized gain (N-gain), and t-tests. The experimental group's mean score increased from 48.91 to 92.36, while the control group's mean score increased from 49.97 to 89.38. The experimental group achieved a higher mean N-gain (85.06%) than the control group (78.61%), with a statistically significant difference, $t(70) = 5.031$, $p < .001$. These findings suggest that integrating STEAM, AR, and *Sipakatau* supports greater improvements in students' learning independence than conventional instruction.

Keywords: Augmented reality, learning independence, Sipakatau

Abstrak: Penelitian ini bertujuan menganalisis efektivitas pembelajaran Science, Technology, Engineering, Arts, and Mathematics (STEAM) berbantuan Augmented Reality (AR) yang mengintegrasikan nilai budaya Sipakatau dalam meningkatkan kemandirian belajar siswa sekolah dasar. Penelitian menggunakan pendekatan kuantitatif dengan desain kuasi eksperimen pretest–posttest nonequivalent control group di SDN 24 Kalibone, Kabupaten Pangkep. Sampel ditentukan melalui teknik total sampling yang melibatkan 72 siswa kelas VI, terdiri atas 33 siswa kelompok eksperimen dan 39 siswa kelompok kontrol. Kelompok eksperimen mengikuti empat pertemuan pembelajaran STEAM terintegrasi AR berbasis Sipakatau, sedangkan kelompok kontrol mengikuti pembelajaran konvensional. Data dikumpulkan menggunakan angket kemandirian belajar 24 butir dan dianalisis melalui statistik deskriptif, N-Gain, serta uji-t. Hasil menunjukkan bahwa rata-rata skor kelompok eksperimen meningkat dari 48,91 menjadi 92,36, sedangkan kelompok kontrol meningkat dari 49,97 menjadi 89,38. Rata-rata N-Gain kelompok eksperimen (85,06%) lebih tinggi dibandingkan kelompok kontrol (78,61%), dengan perbedaan signifikan, $t(70) = 5,031$; $p < 0,001$. Temuan menunjukkan bahwa integrasi STEAM, AR, dan Sipakatau mendukung peningkatan kemandirian belajar yang lebih tinggi dibandingkan pembelajaran konvensional.

Kata kunci: Augmented reality, kemandirian belajar, Sipakatau

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INTRODUCTION

Learning independence is an essential competency to develop in elementary education because it helps students manage, direct, and take responsibility for their own learning. Independent learners can complete tasks with less dependence on teacher guidance and also take the initiative to find information, choose learning strategies, use

resources, and check their understanding. In this study, learning independence is defined using cyclical model of self-regulated learning (SRL), which has three connected phases: forethought, performance, and self-reflection (Zimmerman, 2002). The forethought phase is about setting learning goals. The performance phase is about using and monitoring learning strategies. The self-reflection phase is about evaluating learning outcomes by managing cognitive, metacognitive, motivational, and behavioral processes (Panadero, 2017; Zimmerman, 2002). A systematic review by Olid Luque et al. (2025) also found that SRL programs had a positive effect in primary education, showing the importance of helping students learn to self-regulate from an early age. Indonesia's Merdeka Curriculum likewise emphasizes student-centered learning, the development of students' potential, and the cultivation of character and responsibility (Rahayu et al., 2022). Strengthening learning independence is therefore essential for enabling students not only to acquire knowledge but also to sustain their learning over time

Although learning independence is important, early classroom observations and an interview with a sixth-grade teacher at a public elementary school in South Sulawesi, Indonesia, showed that students had few chances to manage their own learning. In IPAS, many students waited for the teacher's explanations and instructions before starting or finishing assignments. This reliance reduced their chances to show initiative, choose strategies, make decisions, and take responsibility for their learning. Teaching was mostly teacher-centered, and activities relied on physical teaching aids that did not always help students understand certain scientific ideas. Thus, students had few opportunities for independent exploration, interdisciplinary inquiry, and critical thinking. The lessons did not include structured Science, Technology, Engineering, Arts, and Mathematics (STEAM) activities or Augmented Reality (AR) media to support interactive exploration. Furthermore, the lessons did not systematically include the local cultural value, *Sipakatau,* to foster mutual respect, equal participation, and individual responsibility in group work. These results suggest that there is a gap between the stated goal of helping students to become independent learners and the actual opportunities they are provided to develop initiative, decision-making, self-evaluation, and responsibility.

Meeting these challenges demands an instructional approach that both decreases students' reliance on teachers and offers active, exploratory, contextualized, and meaningful learning experiences. Activities that require students to plan their work, generate ideas, identify solutions, make decisions, and reflect on learning outcomes can help to develop learning independence. Systematic instructional interventions, including the development of cognitive, metacognitive, and motivational strategies, can strengthen self-regulation among elementary school. Instruction should therefore be designed to help students progressively manage their learning activities, supported by resources appropriate to their developmental levels and sociocultural contexts (Dignath et al., 2008). One promising alternative is to integrate local *Sipakatau* values into AR-assisted STEAM learning.

STEAM was selected as the instructional approach. It integrates multiple disciplines through inquiry. This study chose STEAM as the instructional approach because it brings together different disciplines through inquiry, exploration, creative activities, and problem-solving. This approach gives students opportunities to learn from direct experience, rather than simply following explanations provided by the teacher. Perignat and Katz-Buonincontro (2019) explained that STEAM connects knowledge and skills from different

disciplines to address real-world problems. Similarly, Quigley et al. (2017) emphasized the role of inquiry and interdisciplinary problem-solving in STEAM learning. Dista et al. (2022) reported that, in elementary education, STEAM learning improved students' learning independence. These findings are relevant to the present study, as STEAM activities allow students to explore different solutions, make their own decisions, and reflect on their work. Such experiences may help students become more confident, take greater responsibility for their learning, and develop the initiative needed to complete learning tasks more independently.

Although STEAM encourages active learning, some IPAS concepts remain difficult for students to understand through verbal explanations and conventional teaching aids alone. AR was selected as a supporting medium because it allows students to observe and interact with three-dimensional virtual objects in a real-world environment. Akçayır and Akçayır (2017) reported that AR offers several educational benefits, particularly in presenting learning materials and increasing student engagement, although its use may involve technical and practical challenges. Garzón and Acevedo (2019) in a meta-analysis, also found that AR positively affects students' learning outcomes. Zhang et al. (2022) noted that AR can support inquiry-based learning by letting students explore abstract ideas, investigate information, and build understanding through interactive activities. These features align with STEAM learning, where students observe problems, look for solutions, and make decisions based on what they find. In this study, AR was used to help students explore information and actively participate in STEAM activities. This experience may assist students in being less reliant on teacher explanations and more confident about their own learning.

STEAM learning is often group-based, with students solving problems, sharing thoughts, and collaborating on solutions. But group work doesn't always mean each student takes part independently. For some students, they may rely on their fellow students to make choices or to complete tasks, but for others, they may not have many opportunities to express their thoughts. To address this, our study integrates the local cultural value of *Sipakatau* into STEAM learning to encourage respectful, balanced, and responsible participation. *Sipakatau* in *Bugis*-Makassar culture is about respecting others, recognizing the dignity of each person, and valuing different opinions (Tang et al., 2023). Earlier studies found that *Sipakatau* can be used in elementary learning materials (Kasi et al., 2024; Wahyuni, 2018), stressed the need to connect science with local culture. In our study, we infused *Sipakatau* values into STEAM activities by motivating students to respect varied viewpoints, share their thoughts, help classmates without taking over, and finish their own work. These steps provide students with choices, control of their learning, and reflection on their work, as they work with others. This is consistent with Zimmerman (2002) idea of self-regulated learning, which highlights students' active role in planning, monitoring, and evaluating their learning. With the inclusion of *Sipakatau* in STEAM, we endeavor to establish a classroom that promotes independence, responsibility, and self-learning through collaboration.

This study integrates STEAM, AR, and Sipakatau because each has a unique but complementary role in assisting students' learning independence. STEAM offers students opportunities to investigate problems, develop ideas, and make decisions through interdisciplinary learning activities (Perignat & Katz-Buonincontro, 2019; Quigley et al.,

2017). AR supports these activities by providing interactive visualizations, which enable students to explore learning materials and to grasp concepts that may be hard to observe directly (Akçayır and Akçayır, 2017; Zhang et al., 2022). But the opportunities to explore and collaborate do not guarantee that all students will participate actively or take responsibility for their learning. In this context, *Sipakatau*, which emphasizes respect for others and recognition of individual dignity, provides a cultural basis for encouraging equitable participation and responsible interactions during group activities (Tang et al., 2023). These learning experiences relate to self-regulated learning, which emphasizes students' ability to plan, monitor, and evaluate their learning processes (Panadero, 2017; Zimmerman, 2002). By bringing these three components together, this study examines whether an instructional approach combining interdisciplinary inquiry, interactive visualization, and culturally grounded learning interactions better supports students' initiative, responsibility, self-confidence, and learning independence than conventional instruction.

Several studies have explored different approaches to improving learning in elementary education. STEAM learning, for example, has been examined in relation to students' learning independence (Dista et al., 2022). AR has also been studied for its role in supporting learning experiences and outcomes (Garzón and Acevedo, 2019; Zhang et al., 2022). Other researchers have discussed how local wisdom, including *Sipakatau* values, can be incorporated into education (Kasi et al., 2024; Tang et al., 2023; Wahyuni, 2018). Recent studies also reported positive outcomes of local wisdom integration into contextual instruction for reading literacy (Syahrul et al., 2026), elementary science achievement (Rahman et al., 2026), and problem-based learning materials for seventh-grade students' environmental literacy (Damopolii et al., 2026). Despite these contributions, studies examining STEAM learning supported by AR assisted with *Sipakatau* values remain limited, particularly those focusing on learning independence among elementary school students. This study focuses on that combination within the *Bugis-Makassar* cultural context of *Pangkep* Regency, South *Sulawesi*. It examines learning independence among sixth-grade students taught through AR-assisted STEAM activities incorporating *Sipakatau* values and compares their outcomes with those of students receiving conventional instruction. The findings are expected to offer further evidence on the potential of combining technology, interdisciplinary learning, and local cultural values to support students' learning independence. The findings are also expected to provide a contextualized alternative for IPAS instruction and practical guidance for elementary school teachers seeking to strengthen both learning independence and student character.

METHODS

This study employed a quantitative, quasi-experimental approach using a pretest–posttest nonequivalent control group design. This design was selected because the study involved intact classes without individual random assignment to the experimental and control groups (Abraham & Supriyati, 2022; Creswell & Creswell, 2018). The study was conducted in 2026 at SDN 24 Kalibone, *Pangkep* Regency, South Sulawesi, Indonesia. The population comprised all 72 sixth-grade students in two classes: Class VI A (39 students) and Class VI B (33 students). Total sampling was employed, meaning that all sixth-grade students were included without additional selection criteria.

Group assignment followed existing class membership rather than individual randomization. Class VI B (33 students) served as the experimental group and received STEAM instruction incorporating AR media and the local cultural value of *Sipakatau*. Class VI A (39 students) served as the control group and received conventional instruction. *Total sampling* was used to recruit participants, whereas the allocation of the experimental and control groups followed the quasi-experimental design.

Table 1. Quasi-experimental research design

Group	Class	N	Pretest	Intervention	Posttest
Experimental	VI B	33	O_1	STEAM + AR + *Sipakatau*	O_2
Control	VI A	39	O_1	Conventional instruction	O_2
Total		72			

The experimental group participated in four structured STEAM sessions integrating AR media and *Sipakatau* values. Activities included introductions to STEAM and AR, virtual-object exploration, interdisciplinary problem-solving, discussions, solution development, and reflection on learning outcomes. *Sipakatau* values were enacted through mutual respect for opinions, helping classmates, active participation, cooperation, and responsibility for assigned tasks. The control group studied the same content through conventional instruction. Both groups completed a pretest before the intervention and a posttest afterward to measure and compare changes in students' learning independence.

The primary measure of learning independence was a 24-item questionnaire using a four-point Likert scale with the response options always, often, sometimes, and never. The The questionnaire was developed to measure seven dimensions of learning independence, namely learning initiative, responsibility, self-confidence, time management, use of learning resources, problem-solving and self-evaluation, and learning interactions reflecting *Sipakatau* values (Deci & Ryan, 2008; Zimmerman, 2002). *Sipakatau* was described by the items of mutual respect, appreciating differences, and building positive social relationships in learning in accordance with the *Sipakatau* philosophy of respecting others and constructing students' moral character (Safitri & Suharno, 2020). Therefore, the instrument directly addressed the aim of the study in assessing the development of students' learning independence through the integration of Sipakatau values in education.

A 34-item observation checklist was used to record how the lessons were implemented, including the application of *Sipakatau* values during classroom activities. Students also completed an achievement test comprising 15 multiple-choice items and five open-ended questions. The lessons were supported by a teaching module, student worksheets, and AR media. These materials were designed to encourage learning independence while incorporating *Sipakatau* values into the learning content and classroom interactions. Respect, cooperation, and the students' cultural context were considered in developing the activities. Before the study began, two experts in elementary education and IPAS reviewed the instruments and learning materials. They examined the relevance of the content to the intended indicators, the accuracy of the material, the construction of the instruments, and the clarity of the language. Attention was also given to how STEAM, AR, and *Sipakatau* were integrated. The learning independence questionnaire received a validation score of 3.63, compared with 3.50 for the *Sipakatau* observation

checklist and 3.70 for the achievement test. Based on the validation criteria, all three instruments fell within the highly valid category. For the learning materials, the overall mean was 3.77. The teaching module received 3.79, followed by the student worksheets at 3.78 and the AR media at 3.75. The experts' comments were subsequently used to revise the instruments before data collection.

The data were analyzed using descriptive and inferential statistics. Descriptive analysis was used for summarizing mean scores and standard deviations of students learning independence before and after intervention. Normalized gain (N-gain) was calculated to investigate the improvement of learning independence in both groups. Before conducting hypothesis testing, the Shapiro-Wilk test was used to assess data normality, while Levene's test was applied to examine the homogeneity of variance. A paired-samples t-test was conducted to compare pretest and posttest scores within the experimental group. An independent-samples t-test was then used to determine whether improvements in learning independence, measured through N-gain scores, differed significantly between the experimental and control groups. All statistical tests were conducted at a significance level of 0.05.

RESULTS AND DISCUSSION

Validation of research instruments and instructional materials

The research instruments and instructional materials were validated by two experts in elementary education and Ilmu Pengetahuan Alam dan Sosial (IPAS; Natural and Social Sciences) instruction. The evaluation covered the alignment of indicators, content accuracy, instrument construction, clarity of language, and integration of STEAM, AR, and the local cultural value of Sipakatau. All instruments and instructional materials were rated highly valid according to the expert assessment criteria applied in this study (Table 2). Revisions based on the validators' feedback focused primarily on item wording, response options, observation scoring instructions, ease of use of the AR media, and the presentation of student worksheets.

Table 2. Expert review of research tools and instructional materials

Component	Mean score	Category
Pretest and posttest instrument	3.70	Highly valid
Learning independence questionnaire	3.63	Highly valid
Sipakatau observation checklist	3.50	Highly valid
Teaching module	3.79	Highly valid
Augmented Reality media	3.75	Highly valid
Student worksheets	3.78	Highly valid
Overall instructional materials	3.77	Highly valid

Empirical validity analysis using corrected item-total correlation was also conducted to assess the quality of the learning independence questionnaire in addition to expert validation with acceptance criterion coefficient of ≥ 0.30. The data of 39 students in the control group and 33 students in the experimental group were analyzed for 24 questionnaire items. In both groups, all items were significantly correlated (ranging from 0.318 to 0.747 in control and 0.367 to 0.776 in experimental). Internal consistency was

tested with Cronbach's alpha. The alpha coefficients were 0.903 (control) and 0.917 (experimental), both above the reference value of $\alpha \geq 0.70$. These results indicated internal consistency, although empirical validity still needs to be verified with regard to the authenticity and independence of response data in both groups (Boateng et al., 2018; Tavakol & Dennick, 2011).

Table 3. Item validity and reliability test of learning independence questionnaire

Test component	Control	Experimental
Number of respondents	39	33
Number of questionnaire items	24	24
Items meeting the correlation criterion ≥ 0.30	24	24
Minimum correlation coefficient	0.318	0.367
Maximum correlation coefficient	0.747	0.776
Cronbach's alpha	0.903	0.917
Reliability criterion	$\alpha \geq 0.70$	$\alpha \geq 0.70$

Learning independence changes

As the descriptive analysis in the progress report shows, the experimental and control groups had fairly comparable baseline mean scores of learning independence (48.91 and 49.97 respectively). Both groups had higher mean scores after instruction. The experimental group was provided with AR-assisted STEAM learning based on *Sipakatau* values, while the control group received conventional instruction. The average posttest score for the experimental group was 92.36, while the control group was 89.38. Descriptively, the experimental group had a higher posttest score than the control group. However, the similarity of their initial scores does not guaranty full groupequivalence because the study used intact classes without random assignment of individuals.

Table 4. Learning independence: descriptive statistics

Statistic	Experimental pretest	Experimental posttest	Control pretest	Control posttest
Mean	48.91	92.36	49.97	89.38
Median	50.00	92.00	50.00	90.00
Variance	27.460	8.051	44.170	6.769
SD	5.240	2.837	6.687	2.602
Minimum	38	86	31	85
Maximum	59	99	65	94
Range	21	13	34	9

Preliminary assumption testing

Before testing the hypotheses, the data were examined for normality and homogeneity of variance to see if they satisfied the assumptions of parametric analyses. Normality was evaluated with the Shapiro-Wilk test at a significance level of 0.05. The progress report indicated that the p-values for the experimental and control groups were 0.598 and 0.329 before the treatment and 0.574 and 0.117 after the treatment. The

respective p-values for N-gain were 0.896 and 0.531. All values were above 0.05, indicating no statistically significant deviations from the normality assumption.

Table 5. Normality test results (Shapiro-Wilk)

Measure	Group	W	n	Sig.
Pretest	Control	0.968	39	0.329
Pretest	Experimental	0.974	33	0.598
Posttest	Control	0.944	39	0.117
Posttest	Experimental	0.973	33	0.574
N-Gain	Control	0.975	39	0.531
N-Gain	Experimental	0.984	33	0.896

We tested for homogeneity of variances using Levene's test with a significance level of 0.05. The progress report showed a Levene statistic of 0.001, df1 = 1, df2 = 70, and p = 0.970. There was no statistically significant difference in variance between the two groups, with a p-value greater than .05. This supported the homogeneity assumption for the test we performed. However, it is important to ensure that the scores used in Levene's test are the same scores that are being compared in the independent-samples t-test.

Table 6. The homogeneity of variance test results from the progress report

Method	Levene statistic	df_1	df_2	Sig.	Conclusion
Levene's test	0.001	1	70	0.970	Homogeneous

Testing hypotheses

To investigate the differences in learning independence before and after the intervention in the experimental group, the paired-samples t-test was used. The average difference between pretest and posttest was -43.455, SD = 5.160, t(32) = -48.373. The findings indicated a significant improvement in learning independence after the implementation of AR-Assisted STEAM Instruction based on *Sipakatau* values.

Table 7. Paired samples t-test results for the experimental group

Comparison	Mean difference	SD	t	df	p
Pretest - posttest	-43.455	5.160	-48.373	32	< 0.001

Instructional effectiveness was evaluated using normalized gain (N-gain). The experimental group achieved a mean N-gain of 85.06% (SD = 5.53), while the control group achieved 78.61% (SD = 5.32). Under the study's criteria, both groups were classified as effective; however, the experimental group had a mean N-gain that was 6.45 percentage points higher. An independent-samples t-test comparing N-gain scores yielded t(70) = 5.031, $p < 0.001$, indicating a statistically significant difference in improvement in learning independence between the groups. These results suggest that AR-assisted STEAM learning grounded in the local cultural value of *Sipakatau* was associated with greater gains in learning independence than conventional instruction.

The results show that using STEAM, AR, and *Sipakatau* led to greater improvement in elementary students' learning independence than conventional teaching. Table 8 shows that the experimental group had a mean N-gain of 85.06%, while the control group had 78.61%, a difference of 6.45 percentage points. An independent-samples t-test confirmed this difference was statistically significant, $t(70) = 5.031$, $p < 0.001$. Both groups improved, but the experimental group's larger gain suggests the integrated approach gave students more chances to develop learning independence. This supports Dista et al. (2022), who also found STEAM learning improved students' independence. This study adds to that by including AR and the local cultural value of *Sipakatau* in one instructional design.

Table 8. Results of n-gain analysis and independent-samples t-test

Group	n	Mean N-gain (%)	SD	Between-group test
Experimental	33	85.06	5.53	$t(70) = 5.031$
Control	39	78.61	5.32	$p < 0.001$

These learning experiences explain the experimental group's improvement across the four instructional sessions. Students took part in STEAM activities that included exploring virtual objects with AR, solving cross-curricular problems, discussing ideas, developing solutions, and reflecting on their work. The learning experience also included *Sipakatau* values by encouraging respect for different opinions, helping each other, active participation, and responsibility for tasks. Rather than working separately, STEAM, AR, and *Sipakatau* worked together to support a learning process in which students explored information, considered solutions, and participated.

Bringing these three elements together matters because building learning independence takes more than letting students work without direct teacher help. Students also need resources, chances to make decisions, and an environment that supports responsible participation. AR provides students with interactive visuals to *explore* IPAS concepts responsibly in group work. These experiences fit with Zimmerman (2002) model of self-regulated learning, which highlights students' roles in planning, monitoring, and reflecting on their learningand think about solutions in STEAM activities. At the same time *Sipakatau* values helped shape how students worked together, focusing on respect and responsibility. These activities may have helped students take more control of their learning while maintaining good relationships with classmates. This is in line with the finding that AR supports interactive learning and the focus on the value of *Sipakatau* in character education (Tang et al., 2023; Zhang et al., 2022). In this study, these ideas help explain the benefits of combining technology and cultural values for learning.

Local wisdom has been studied in Indonesian classrooms with various teaching approaches. Syahrul et al. (2026) reported that contextual teaching and learning improved reading literacy and classroom participation of students in their study of Dayak Belusu local wisdom. Rahman et al. (2026) studied elementary science and found that students who learned through a contextual approach based on local wisdom performed better than those who received direct instruction. Damopolii et al. (2026) evaluated a different setting. They studied the use of problem-based books with Papuan local wisdom in seventh-grade students. Their results suggested a greater degree of environmental literacy. Although the three studies addressed different topics and learning outcomes, each provides an example

of how local knowledge can be integrated into classroom teaching. However, none of them studied the combination of STEAM, AR, and *Sipakatau* to improve students' learning independence.

Another key finding is about how collaborative learning relates to individual learning independence. While STEAM activities involved group work, adding *Sipakatau* showed that cooperation should include respect for each person's contributions and responsibility for tasks. Here, learning to be independent does not mean working alone. Students can be encouraged to discuss ideas, make decisions and take responsibility for their learning, which can help them work together more independently. This view is in line with Fatmi et al. (2024) that found that materials built on local wisdom could enhance students' independence. This study adds to that by integrating local cultural values to interdisciplinary technology-based learning, not only using culturally based materials.

The findings should also be viewed in terms of the areas measured by the learning independence questionnaire. The tool covered the learning initiative, responsibility, self-confidence, time management, use of resources, problem-solving, self-evaluation, and interactions that reflect *Sipakatau* values. The instructional activities were to provide students opportunities to grow in these areas. The exploration of virtual objects and the creation of solutions helped students to use resources and solve problems, while discussions and reflection promoted participation, responsibility and evaluation. The analysis, however, looked at overall learning independence scores, not changes within each area. Therefore, the improvement observed should be considered as a change in overall learning independence related to the integrated approach

The control group also showed a substantial improvement with a mean N-gain of 78.61%. The findings imply that students could develop higher levels of learning independence even through traditional classroom instruction. Nevertheless, the experimental group obtained a higher mean N-gain of 85.06%. The difference may be due to the learning experiences provided during the intervention. Through STEAM activities supported by AR, students had opportunities to explore ideas, make decisions, and reflect on their learning. The integration of *Sipakatau* values also served to highlight respect and cooperation in classroom interactions. These experiences may help explain the stronger improvement seen in the experimental group. Although the contribution of each component cannot be determined separately, the results suggest that combining STEAM, AR, and *Sipakatau* may be a useful way to support learning independence while keeping classroom activities connected to students' cultural backgrounds.

CONCLUSION

Limitations of this study included the use of two preexisting sixth-grade classes in a single public elementary school, the lack of individual random assignment, and the delivery of an intervention over four instructional sessions. These conditions restrict the generalizability of the findings and do not allow conclusions about long-term effects. Furthermore, the individual contributions of STEAM, AR, and *Sipakatau* could not be determined, as they were implemented in an integrated approach. Overall learning independence was also analyzed, not the changes in individual dimensions. Future studies should include more schools, a longer period of intervention, and an examination of the contribution of each of the instructional components.

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REFERENCES

Abraham, I., & Supriyati, Y. (2022). Desain kuasi eksperimen dalam pendidikan: literatur review. *Jurnal Ilmiah Mandala Education*, *8*(3). 2476–2482. https://doi.org/10.58258/jime.v8i3.3800

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, *20*, 1–11. https://doi.org/10.1016/j.edurev.2016.11.002

Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quiñonez, H. R., & Young, S. L. (2018). Best Practices for Developing and Validating Scales for Health, Social, and Behavioral Research: A Primer. *Frontiers in Public Health*, *6*, 149. https://doi.org/10.3389/fpubh.2018.00149

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (Fifth edition). SAGE.

Damopolii, I., Imbiri, L., Jeni, J., Nasir, N. I. R. F., Nunaki, J. H., Siregar, N. N., & Winarno, N. (2026). Adding Papuan local wisdom in problem-based book: The effect on student environmental literacy. *Journal of Research in Instructional*, *6*(1), 400–412. https://doi.org/10.30862/jri.v6i1.21

Deci, E. L., & Ryan, R. M. (2008). Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian Psychology / Psychologie Canadienne*, *49*(3), 182–185. https://doi.org/10.1037/a0012801

Dignath, C., Buettner, G., & Langfeldt, H.-P. (2008). How can primary school students learn self-regulated learning strategies most effectively? *Educational Research Review*, *3*(2), 101–129. https://doi.org/10.1016/j.edurev.2008.02.003

Dista D. X., Marta, R., & Mufarizuddin. (2022). Peningkatan Kemandirian Belajar Siswa dengan Menerapkan Pembelajaran STEAM di Sekolah Dasar. *JIKAP PGSD: Jurnal Ilmiah Ilmu Kependidikan*, *6*(1), 16–26. https://doi.org/https://doi.org/10.26858/jkp.v6i1.30069

Fatmi, N., Sakdiah, H., Alchalil, A., & Fitriani, H. (2024). Application of ethnopedagogical module in natural sciences based on local wisdom towards learning independence in thematic learning. *Jurnal Phi Jurnal Pendidikan Fisika Dan Fisika Terapan*, *10*(2), 33. https://doi.org/10.22373/p-jpft.v10i2.23552

Garzón, J., & Acevedo, J. (2019). Meta-analysis of the impact of Augmented Reality on students' learning gains. *Educational Research Review*, *27*, 244–260. https://doi.org/10.1016/j.edurev.2019.04.001

Kasi, Y. F., Widodo, A., Samsudin, A., Riandi, R., Novia, N., Sukmawati, W., & Shidiq, A. S. (2024). Integrating Local Science and School Science: The Benefits for Preserving

Local Wisdom and Promoting Students' Learning. *PAEDAGOGIA*, *27*(1), 24-37 https://doi.org/10.20961/paedagogia.v27i1.83925

Olid Luque, M., Ayllón Salas, P., Arco Tirado, J. L., & Fernández Martín, F. D. (2025). Impact of Self-Regulated Learning Programs in Primary Education: A Systematic Review. *Psychology in the Schools*, *62*(3), 734–755. https://doi.org/10.1002/pits.23352

Panadero, E. (2017). A Review of Self-regulated Learning: Six Models and Four Directions for Research. *Frontiers in Psychology*, *8*, 422. https://doi.org/10.3389/fpsyg.2017.00422

Perignat, E., & Katz-Buonincontro, J. (2019). STEAM in practice and research: An integrative literature review. *Thinking Skills and Creativity*, *31*, 31–43. https://doi.org/10.1016/j.tsc.2018.10.002

Quigley, C. F., Herro, D., & Jamil, F. M. (2017). Developing a Conceptual Model of STEAM Teaching Practices. *School Science and Mathematics*, *117*(1–2), 1–12. https://doi.org/10.1111/ssm.12201

Rahayu, R., Rosita, R., Rahayuningsih, Y. S., Hernawan, A. H., & Prihantini, P. (2022). Implementasi Kurikulum Merdeka Belajar di Sekolah Penggerak. *Jurnal Basicedu*, *6*(4), 6313–6319. https://doi.org/10.31004/basicedu.v6i4.3237

Rahman, R., Kusumaningrum, S. R., & Mardhatillah, M. (2026). Science learning with a contextual approach based on local wisdom for to enhance elementary school students achievement. *Journal of Research in Instructional*, *6*(1), 370–383. https://doi.org/10.30862/jri.v6i1.59

Safitri, A., & Suharno, S. (2020). Budaya Siriâ€™ Na Pacce dan Sipakatau dalam Interaksi Sosial Masyarakat Sulawesi Selatan. *Jurnal Antropologi: Isu-Isu Sosial Budaya*, *22*(1), 102–111. https://doi.org/10.25077/jantro.v22.n1.p102-111.2020

Syahrul, S., Kusumaningrum, S. R., Arifin, S., Admoko, A., & Mas'ula, S. (2026). Strengthening reading literacy through contextual teaching and learning with Dayak Belusu local wisdom. *Journal of Research in Instructional*, *6*(1), 78–91. https://doi.org/10.30862/jri.v6i1.14

Tang, M., Ismail, Samsuduha, S., & Markuna. (2023). Sipakatau Culture and Character Education (Ethnographic Studies on the Bugis Barang Soppeng Society of South Sulawesi). *Edukasi Islami: Jurnal Pendidikan Islam*, *12*(4), 2485–2496. https://doi.org/10.30868/ei.v12i04.4937

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

Wahyuni, S. (2018). Pengembangan Media Audio Visual Berbasis Budaya Lokal Sipakatau Dalam Pembelajaran IPS Pada Peserta Didik SD Se Gugus SDN 57 Campaga Kabupaten Bantaeng. *Phinisi Integration Review*, *1*(2), 141-148. https://doi.org/10.26858/pir.v1i2.6648

Zhang, J., Li, G., Huang, Q., Feng, Q., & Luo, H. (2022). Augmented Reality in K–12 Education: A Systematic Review and Meta-Analysis of the Literature from 2000 to 2020. *Sustainability*, *14*(15), 9725. https://doi.org/10.3390/su14159725

Zimmerman, B. J. (2002). Becoming a Self-Regulated Learner: An Overview. *Theory Into Practice*, *41*(2), 64–70. https://doi.org/10.1207/s15430421tip4102_2