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Developing deep learning-oriented teaching materials integrated with Bugis-Makassar and Nusantara local wisdom to enhance fifth-grade students' critical thinking in elementary science and social studies

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Article

Keywords:

Posted Date: November 23rd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11477126/v1

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Additional Declarations: No competing interests reported.

Developing deep learning-oriented teaching materials integrated with Bugis-Makassar and Nusantara local wisdom to enhance fifth-grade students' critical thinking in elementary science and social studies

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Abstract

Elementary science and social studies (Ilmu Pengetahuan Alam dan Sosial, IPAS) in Indonesia are still dominated by memorization-oriented instruction and generic textbooks that seldom connect concepts to students' cultural surroundings. This research and development study, following the ten-step Borg and Gall model, developed Phase C IPAS teaching materials for fifth-grade students that operationalize the national deep learning approach (mindful, meaningful, and joyful) and integrate Bugis-Makassar and wider Nusantara local wisdom, and examined their validity, practicality, and effectiveness in improving critical thinking. The preliminary study involved 42 teachers and 77 students in Makassar, Indonesia; five experts validated the product and instruments; and the materials were field-tested in one school (22 students), six schools (176 students), and ten schools (583 students: 292 in experimental and 291 in control classes). The operational stage used a quasi-experimental posttest-only control group design. The final package comprised four units and 12 topics embedding 20 local wisdom practices. Mean Aiken's V values were 0.705 for the teaching materials, 0.718 for the teaching module, and 0.728–0.837 for the research instruments. In the operational stage, teacher implementation reached 89.9%, student activity 88.6%, teacher responses 89.1%, and student responses 85.2%, all higher than in the preliminary stage. Experimental classes scored higher than control classes in all ten schools (mean of school means 81.73 vs. 54.14; $t = 25.02–34.64$, all $p < 0.001$), with advantages on all six Facione indicators, largest for inference and smallest for interpretation. The convergence of test, observation, and response data indicates that the deep learning-oriented, local wisdom-based teaching materials are valid and practical and are associated with substantially higher critical thinking scores among fifth-grade students in IPAS, although the posttest-only design with non-randomised intact classes and a researcher-developed test aligned with the materials limits causal inference.

Introduction

Basic education is increasingly expected to do more than transmit content; it should cultivate students' capacity to interpret information, weigh evidence, and reach reasoned decisions about real problems (OECD, 2019, 2023). Critical thinking, defined by Facione (2011) as purposeful, self-regulatory judgment expressed through interpretation, analysis, evaluation, inference, explanation, and self-regulation, is therefore a central goal of elementary science and social studies. In Indonesia, the Merdeka Curriculum combines the natural and social sciences into a single subject, Ilmu Pengetahuan Alam dan Sosial (IPAS), so that children can examine natural phenomena and social life as connected systems. Ideally, IPAS lessons and the materials that support them should help students move from recalling facts to analyzing, evaluating, and applying ideas in their own lives (Maulinda, 2022; Salmia et al., 2024b).

International and local evidence suggests that this goal is far from being met. In PISA 2018, Indonesia ranked 74th of 79 participating countries, with a mean science score of 396 compared with

the OECD average of 489 (OECD, 2019; Yuliati & Lestari, 2018). PISA 2022 again showed that approximately 74.5%, 81.7%, and 65.8% of Indonesian students did not reach baseline proficiency in reading, mathematics, and science, respectively, while fewer than 1% reached the highest proficiency levels associated with higher-order thinking (OECD, 2023). Analyses of these results have attributed low performance partly to mechanistic, memorization-oriented instruction and to the weak relevance of school content to students' daily lives (OECD, 2019). Preliminary observations in elementary schools in Makassar, South Sulawesi, during the 2024/2025 school year showed a similar picture: only 45% of fifth-grade students reached the minimum mastery criterion in IPAS. Interviews and focus group discussions with 42 teachers and 77 students indicated that available materials seldom contained investigative tasks or higher-order questions, that lessons were largely teacher-centered, and that students rarely took part in extended discussion or exploratory projects.

Indonesia's national response has been to promote a deep learning approach (*pembelajaran mendalam*). In this educational sense, the term does not refer to machine learning; it describes learning that is mindful (conscious and self-regulated), meaningful (connected to prior knowledge and real contexts), and joyful (intrinsically engaging). The approach draws on a long tradition distinguishing deep from surface approaches to learning, in which deep learners seek meaning, relate ideas, and examine evidence critically rather than reproducing information (An & Gao, 2022; Entwistle & Ramsden, 2015; Ohlsson, 2011). New pedagogies for deep learning emphasize authentic problems, collaboration, and reflection as conditions for transferable understanding (Fullan & Langworthy, 2014). Yet a policy-level commitment to deep learning does not automatically change classroom practice. Teachers need concrete materials that translate these principles into lesson sequences, tasks, and assessments.

Local wisdom offers a promising context for such materials. Culturally responsive and culturally relevant pedagogy holds that learning becomes more meaningful when it builds on students' cultural identities, knowledge, and lived experience (Gay, 2018; Hollins, 2008; Ladson-Billings, 1995). Local wisdom, understood as knowledge and values accumulated through a community's long interaction with its environment, is dynamic and open to new knowledge rather than a static heritage (Wagiran, 2012). In South Sulawesi, Bugis-Makassar values such as *sipakatau* (mutual respect for human dignity), *sipakainga* (reminding one another), *sipakalebbi* (mutual appreciation), *sipamase-mase* (mutual care), and *pattulung-tulungan* (mutual help) shape everyday social life (Khaeruddin et al., 2020). Across the archipelago, practices such as *Subak* irrigation in Bali, *Sasi* resource closures in Maluku and Papua, the *Pranata Mangsa* seasonal calendar in Java, and Dayak forest stewardship encode ecological knowledge directly relevant to IPAS topics such as ecosystems, natural resources, and disaster mitigation. Many of these practices also express long-standing principles of environmental stewardship, which makes them a natural bridge between school science and education for sustainability.

Studies of local wisdom-based materials in Indonesian elementary schools have reported high expert validity and moderate-to-high gains in learning outcomes and critical thinking, with N-gain values between 0.56 and 0.72 (Duratun & Rokhman, 2024; Mulyani, 2025; Ni et al., 2024; Pristiwanti et al., 2024). A meta-analysis of local wisdom-oriented IPAS modules likewise concluded that such modules improve conceptual understanding while strengthening cultural identity (Alwi & Suarni, 2024). However, most of these studies were conducted in a single school, used general achievement measures rather than a full critical thinking framework, and did not explicitly operationalize the deep learning approach. Reviews of local wisdom in elementary learning media and of deep learning in social studies note that research combining the two remains limited, which makes it difficult to build a coherent implementation framework (Setiawaty et al., 2025; Yunita, 2025). In Makassar, teachers also face constraints in time, facilities, and expertise for designing such materials on their own (Burhan et

al., 2024). The national IPAS textbook for Grade 5, for example, contains no references to Bugis-Makassar culture, and its comprehension questions are dominated by lower-order thinking.

Accordingly, the distinctive contribution of the present study does not lie in the use of a research and development model itself, which is well established in educational research, but in three design features examined together: an explicit translation of the mindful–meaningful–joyful framework into a consistent topic structure; the functional, rather than decorative, embedding of local wisdom as the context for concepts, problems, and critical thinking stimuli; and evaluation across ten schools using an instrument aligned with all six of Facione's critical thinking indicators.

This study, therefore, aims to develop IPAS teaching materials for fifth-grade students that integrate the deep learning approach with Bugis-Makassar and wider Nusantara local wisdom, and to evaluate them through a full cycle of research and development. The study is guided by the following research questions: (1) What does the prototype of deep learning-oriented, local wisdom-based IPAS teaching materials look like? (2) How valid are the developed materials and instruments? (3) How practical are the materials for teachers and students? (4) How effective are the materials in improving fifth-grade students' critical thinking in IPAS?

The remainder of this paper is organized as follows. Section "Methods" describes the research design, participants, instruments, data analysis, and development procedures. Section "Results" presents the needs analysis, the prototype, and the evidence on the validity, practicality, and effectiveness of the teaching materials. Section "Discussion" interprets these findings in relation to previous research and sets out the limitations of the study and directions for future research. Section "Conclusions" summarizes the main findings.

Methods

Research design

This study employed a research and development (R&D) design based on the ten-step model of Borg and Gall (1983): research and information collecting, planning, developing the preliminary product, preliminary field testing, main product revision, main field testing, operational product revision, operational field testing, final product revision, and dissemination and implementation. The model was selected because it requires a product to be revised iteratively on the basis of empirical data at increasing scales. Quantitative data were used to judge validity, practicality, and effectiveness, while qualitative data from interviews, validator comments, and open responses informed each revision. The operational field test used a quasi-experimental posttest-only control group design. Intact fifth-grade classes were assigned to experimental or control conditions; experimental classes learned with the developed materials, whereas control classes followed regular instruction with the national textbook. The study was conducted from March 2025 to May 2026.

Participants

The study took place in public elementary schools in Makassar, the capital of South Sulawesi Province, Indonesia. The preliminary study involved 42 teachers and 77 students in interviews and focus group discussions, and 15 fifth-grade teachers from different schools completed a structured needs-analysis questionnaire. Five experts validated the product and instruments: a deep learning and IPAS content expert, a learning media and visual design expert, a language and readability expert, an elementary education practitioner, and a South Sulawesi local wisdom expert.

Field testing proceeded in three expanding stages. The preliminary field test was conducted in one school with one teacher and 22 students. The main field test involved six schools, six teachers, and

176 students. The operational field test involved ten schools, ten teachers, and 583 students: 292 in experimental classes and 291 in control classes. Schools were selected through stratified purposive sampling. Strata were defined by geographical setting (coastal and urban areas, which differ in access, facilities, and socio-economic conditions) and by school type (regular state schools, SDN, and former presidential-instruction schools, SD Inpres, which often differ in management and facilities). This approach followed Borg and Gall's (1983) recommendation that operational testing take place in 10–30 schools whose characteristics resemble the settings in which the finished product will be used. The study was designed to evaluate the product rather than to compare schools, and the participants at each stage are summarized in Table 1.

Table 1 Development stages, participants, data sources, and outputs.

Stage (Borg and Gall step)	Period	Setting	Participants	Data sources	Output
Research and information collecting (1)	Mar–May 2025	Elementary schools in Makassar	42 teachers and 77 students (interviews, FGD); 15 teachers (questionnaire)	Interviews, FGD, observation, needs questionnaire, textbook and curriculum analysis, literature review	Map of needs and design requirements
Planning and preliminary product (2–3)	Jun–Nov 2025	University	5 expert validators	Expert validation sheets, written comments	Prototype (Draft I); validated instruments
Preliminary field testing and revision I (4–5)	From Dec 2025	1 school; Unit 1	1 teacher, 22 students	Implementation observation, response questionnaires, interviews	Draft II
Main field testing and revision II (6–7)	To May 2026	6 schools; Unit 2	6 teachers, 176 students	Implementation observation, response questionnaires	Draft III
Operational field testing (8)	To May 2026	10 schools; Units 3 and 4	10 teachers, 583 students (292 experimental, 291 control)	Implementation observation, response questionnaires, critical thinking test	Practicality and effectiveness evidence
Final revision and dissemination (9–10)	2026	—	—	Teacher and student feedback	Final product, publications, teacher workshops

Instruments

Data were collected using eight instruments developed from blueprints aligned with the constructs to be measured (Table 2). The validation sheet for the teaching materials comprised 66 items in five domains, rated on a five-point scale, and the validation sheet for the teaching module comprised 128 indicators grouped into 32 aspects in five domains, rated on a four-point scale. The questionnaires, observation sheets and critical thinking test were validated on five-point scales and the interview guide on a four-point scale. The teacher and student response questionnaires each contained 50 items, rated on a five-point scale from strongly disagree (1) to strongly agree (5), covering visual appearance, usefulness for IPAS, the feasibility of IPAS and local wisdom content, impact on student activity, and ease of use; the student version was worded in child-friendly first-person statements for children aged 10–11 years. Two observation sheets recorded teacher implementation (23 items; maximum score 92) and student activity (27 items; maximum score 108), and an interview guide contained 25 questions in six aspects.

The critical thinking test consisted of ten essay items built around six stimulus texts on Nusantara local wisdom. Items were mapped to Facione's six indicators: interpretation, analysis, evaluation, explanation, inference, and self-regulation (reflection) (Facione, 2011). Interpretation, analysis, evaluation, and explanation were each assessed by two items, and inference and self-regulation by one item each; item 9, which addresses both interpretation and analysis, was scored under interpretation. Each response was scored with an analytic rubric from 1 to 7, and the total score (maximum 70) was converted to a 0–100 scale. Before use, all instruments were reviewed by the five experts, who assessed construct alignment, relevance, wording clarity, and the appropriateness of the response format; their written recommendations were incorporated before administration, and content validity was quantified using Aiken's V.

Table 2 Constructs, indicators, and measurement forms of the instruments.

Instrument	Constructs or aspects	Measurement form
Validation sheet for teaching materials	IPAS content and accuracy; media and visual design; language; practicality for teachers and students; South Sulawesi local wisdom	66 items in 5 domains; five-point scale; 5 validators
Validation sheet for teaching module	Content; media and visual design; language; elementary practice; local wisdom	128 indicators (32 aspects) in 5 domains; four-point scale
Teacher response questionnaire	Visual appearance; usefulness for IPAS; feasibility of IPAS and local wisdom content; impact on student activity; ease of use	50 items; five-point scale
Student response questionnaire	Same five aspects in child-friendly first-person statements	50 items; five-point scale
Teacher implementation observation sheet	Deep learning syntax, critical thinking stimulation, local wisdom integration, active learning, media use	23 items; four-point scale; maximum 92
Student activity observation sheet	Engagement in deep learning activities, critical thinking, local wisdom use, collaboration, communication, worksheets	27 items; four-point scale (4 = more than 85% of students active); maximum 108
Interview guide	Teaching materials, local wisdom, critical thinking, learning design, language, feasibility	25 questions in 6 aspects
Critical thinking test	Interpretation, analysis, evaluation, explanation, inference, self-regulation	Ten essay items based on six local wisdom stimulus texts; analytic rubric 1–7 per item; 0–100

Data analysis

Content validity was analyzed with Aiken's V (Aiken, 1985):

$$V = \sum s / [n(c - 1)] \quad (1)$$

where $s = r - l_o$, r is the rating given by a validator, l_o is the lowest possible rating, c is the number of rating categories, and n is the number of validators. Values of 0.80 or higher were interpreted as highly valid, 0.60–0.79 as valid, 0.40–0.59 as moderately valid, and below 0.40 as less valid.

Practicality was analyzed from teacher and student responses as follows:

$$P = (\Sigma x / \Sigma x_i) \times 100\% \quad (2)$$

where Σx is the obtained score and Σx_i is the maximum score. Scores of 81–100% were classified as highly practical, 61–80% as practical, 41–60% as moderately practical, and 40% or lower as impractical. Implementation was expressed as the percentage of the maximum observation score and classified as very good (≥86%), good (71–85%), fair (56–70%), or poor (< 56%), following Nieveen and Folmer (2013).

Effectiveness was analyzed by comparing the critical thinking scores of experimental and control classes, with the individual student as the unit of analysis. Normality was examined separately for each group in each school with the Kolmogorov–Smirnov test with Lilliefors correction and the Shapiro–Wilk test, and homogeneity of variance with Levene's test. Scores were then compared with

independent-samples t-tests for each school (α = 0.05; Sugiyono, 2019); Welch's correction was applied where Levene's test was significant, and Cohen's d was computed as the effect size. As a robustness check, a two-way analysis of variance with group and school as factors was fitted to all scores. The analyses were run in Python (pandas, NumPy and SciPy), and the scripts are provided with the data. The qualitative data from interviews and validator comments were analyzed through data reduction, data display, and conclusion drawing, and were used to explain quantitative trends and to guide each revision.

Research procedures

The research procedure followed the ten steps of the Borg and Gall model, grouped into six stages. It began with research and information collecting, followed by planning and the development of the preliminary product, expert validation, and three field tests of increasing scale, each followed by a revision. The final revision produced the finished product, which was then disseminated through publications and teacher workshops. The overall procedure, including the participants and outputs at each stage, is summarized in Fig. 1.

The developed product was a teaching material package for IPAS Phase C, Grade 5, Semester 2. It expands the scope of Chapters 5–8 of the national textbook into four units and 12 topics: Unit 1, *How We Live and Grow* (respiration, digestion, and growth); Unit 2, *Indonesia: Its Shape, Biodiversity, and Natural Resources*; Unit 3, *My Region, My Pride* (cultural diversity, regional economic activities, and regional products); and Unit 4, *My Beloved, Fragile Earth* (natural hazards, human-caused environmental damage, and their social and economic impacts). Every topic follows the same sequence: an essential question, core content, vocabulary and "Did you know?" boxes, three deep learning activities (mindful, meaningful, and joyful) each containing critical thinking questions, a self-check, a reflection, and a topic summary linking concept, local wisdom, and values. The package also includes a teacher module with deep learning syntax for each topic, student worksheets (LKPD), a critical thinking test, observation instruments, and rubrics for critical thinking and character.

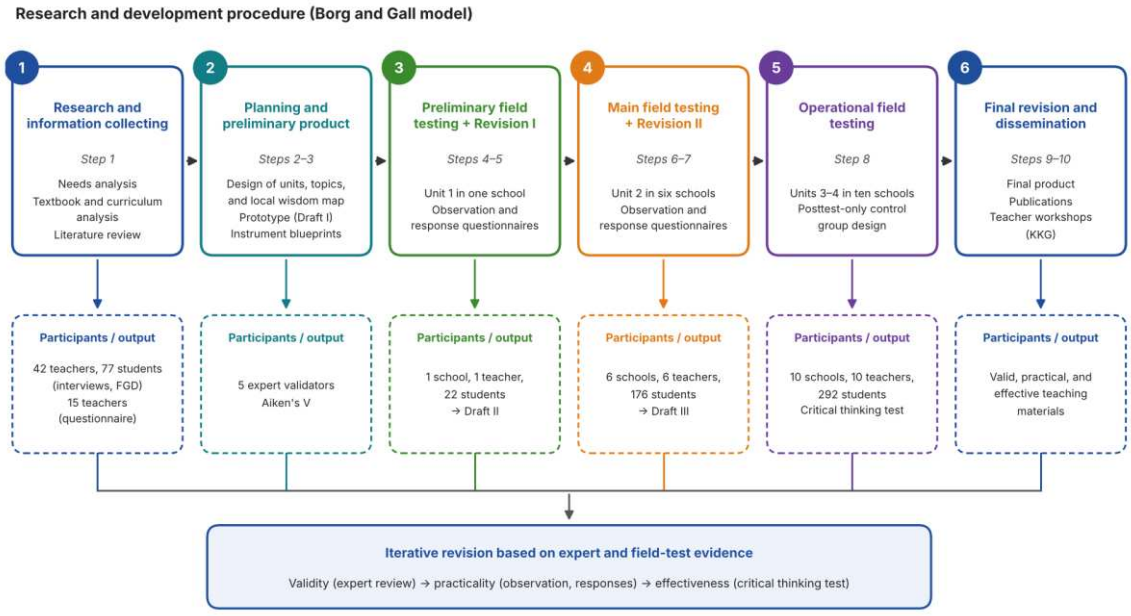


Fig. 1 Research procedures used in the development of the teaching materials.

Ethical considerations

The study was endorsed by the Graduate School and the Institute for Research, Development, and Community Service (Lembaga Penelitian, Pengembangan dan Pengabdian kepada Masyarakat [LP3M]), Universitas Muhammadiyah Makassar, and was conducted under research permits from the South Sulawesi Provincial and Makassar City licensing offices and the Makassar City Education Office. All procedures involving human participants were conducted in accordance with relevant institutional and governmental regulations and with the principles of the Declaration of Helsinki. Principals approved data collection in each school. Informed consent was obtained from teachers and from the parents or guardians of participating students, with students' assent. Participation was voluntary, and participants were informed about the purpose of the research and the confidentiality of their responses.

Results

The findings indicate that teachers in Makassar valued local wisdom and deep learning but lacked the understanding and ready-made materials needed to put them into practice. These needs shaped a prototype in which local wisdom serves as the context for concepts, problems, and critical thinking tasks. Expert ratings placed the resulting product and instruments in the valid to highly valid range, so the main challenge did not lie in the acceptability of the design, but rather in how well teachers and students could use it in real classrooms.

Practicality rose steadily across the three field tests, with student activity lagging behind teacher implementation until the final stage. In the operational test, experimental classes scored higher than control classes in every school and on every critical thinking indicator. Taken together, these findings provide a clear basis for discussing the contribution of deep learning-oriented, local wisdom-based teaching materials to elementary IPAS learning.

Teachers lacked the understanding and materials needed for deep, culturally grounded IPAS learning

Most of the 15 teachers who completed the needs questionnaire reported insufficient understanding on all five indicators (Table 3). On average, 80.0% of responses fell in the "very limited" or "limited" categories, and the proportion was highest for prior experience of integrating local wisdom into IPAS (86.7%). Interview data reinforced this finding. Teachers valued local wisdom and deep learning but had rarely put them into practice.

> "I strongly support developing IPAS materials that integrate deep learning and local wisdom, because it makes learning more interesting and relevant. But I need guidance on how to apply it effectively." (Teacher 3)

> "No, I have never taught IPAS by integrating local wisdom directly. I need more guidance on how to use it to stimulate students' critical thinking." (Teacher 4)

Analysis of the Grade 5 national IPAS textbook revealed two further gaps. The first was cultural: the words "Bugis," "Makassar," and "Sulawesi" did not appear, and regional examples came mainly from outside Sulawesi. The second was cognitive: questions were dominated by recall, comprehension, and application, and the 18 "comprehension check" sections had no standardized rubric for critical thinking. Earlier studies of local wisdom-based materials reported N-gain values of 0.56–0.72 for critical thinking (Duratun & Rokhman, 2024; Mulyani, 2025; Ni et al., 2024; Pristiwanti et al., 2024), which served as a reference point when the prototype was designed. Because the operational test used

a posttest-only design, N-gain values could not be computed in the present study, so these figures are not directly comparable with the results reported below.

Table 3 Teachers' needs-analysis responses (n = 15) and design implications.

Indicator	Very limited (n)	Limited (n)	Under-stand (n)	Fully under-stand (n)	Limited or very limited (%)	Design implication
Implementing the curriculum in IPAS	1	11	3	0	80.0	Align topics with Phase C learning outcomes; include implementation guidance
Integrating local wisdom in IPAS	2	10	3	0	80.0	Explicit "knowledge bridge" box in every topic linking local wisdom to concepts
Developing deep learning and local wisdom materials	2	10	3	0	80.0	Teacher quick guide and a consistent mindful–meaningful–joyful activity cycle
Need for deep learning and local wisdom materials	4	7	2	2	73.3	Ready-to-use, self-contained materials and worksheets
Prior experience of local wisdom-based IPAS	4	9	2	0	86.7	Concrete examples, step-by-step lesson guidance, critical thinking rubric

Note: Percentages are calculated from the 15 respondents

The prototype embedded 20 local wisdom practices across four units

The prototype distributed 20 local wisdom practices across the four units according to their conceptual fit with each topic (Table 4). Thirteen came from Bugis-Makassar culture, chosen for their closeness to students' daily lives, and seven came from other regions of Indonesia to broaden students' view of national diversity. Unit 2 contained the most (10), because its national scope on geography, biodiversity, and natural resources called for examples from many regions; Units 3 and 4 contained eight each and Unit 1 seven. Local wisdom was integrated through four mechanisms: as an opening context that activates prior knowledge, as a bridge to scientific concepts, as an authentic problem to investigate, and as material for critical reflection.

Table 4 Structure of the prototype and examples of integrated local wisdom.

Unit	IPAS topics	Examples of local wisdom (origin)	Role in learning
1 How We Live and Grow	Respiration; digestion and nutritious local food; growth and development	*Kamase-masea* (Ammatoa Kajang); *Tri Hita Karana* (Bali); *Mappasere ri Lino*, *Tudang Sipulung*, *Pattulung-tulungan*, *Sipamase-mase* (Bugis-Makassar)	Living in harmony with nature; gratitude for food; mutual care in supporting children's growth
2 Indonesia: Its Shape, Biodiversity, and Natural Resources	Geography of Indonesia; biodiversity (Wallace–Weber line, Bantimurung); living and non-living resources	Star navigation and *Pinisi* boats (Bugis); *Pranata Mangsa* (Java); *Sasi* and *Mane'e* (Maluku–Papua); *Lubuk Larangan* (Minangkabau); *Tana' Ulen* (Dayak)	Indigenous science and customary rules that conserve natural resources
3 My Region, My Pride	Cultural diversity; coastal and highland economic activities; regional products	*Pakarena*, *Sinrilik*, *Baju Bodo*, *Tongkonan*, Sengkang silk, Toraja coffee; values of *reso* (hard work) and *lempu'* (honesty)	Students investigate, document, and present regional culture and products as authentic projects
4 My Beloved, Fragile Earth	Natural hazards; plastic waste and environmental damage; social and economic impacts	Earthquake-resistant stilt houses (Bugis-Makassar); *Smong* (Simeulue, Aceh); Losari mangroves; Lake Tempe; waste banks; *Siri' na Pacce*	Traditional models of disaster mitigation and environmental stewardship

The materials and instruments were valid to highly valid

All eight products and instruments reached at least the valid category (Table 5). The teaching materials obtained a mean Aiken's V of 0.705 across 66 items and five domains, and no domain fell below 0.60, although at item level 4 of the 66 items had V below 0.60 (minimum 0.550). Each domain was rated highest by the validator specializing in it: 0.865 for content by the content expert, 0.893 for media by the media expert, 0.904 for language by the language expert, 0.917 for practicality by the practitioner, and 0.857 for local wisdom by the local wisdom expert. The teaching module reached a mean of 0.718, with all 32 aspects at least valid (0.633–0.800), although 7 of the 128 indicators had item-level V below 0.60 (minimum 0.467). The two observation sheets were the strongest instruments (0.833 and 0.837, highly valid), and the critical thinking test reached 0.778. Validators recommended only minor revisions, so the product was declared valid and ready for field testing.

Table 5 Content validity of the product and instruments (five validators).

Product or instrument	Items	Mean Aiken's V	Range across domains or aspects	Category
Teaching materials	66	0.705	0.692–0.719	Valid
Teaching module	128 (32 aspects)	0.718	0.708–0.726	Valid
Teacher response questionnaire	25	0.738	0.720–0.760	Valid
Student response questionnaire	25	0.758	0.750–0.760	Valid
Teacher implementation observation sheet	23	0.833	0.800–0.900	Highly valid
Student activity observation sheet	27	0.837	0.800–0.867	Highly valid
Interview guide	25	0.728	0.720–0.733	Valid
Critical thinking test	30	0.778	0.767–0.800	Valid

Note: The questionnaires were validated on 25 representative items of the 50-item versions

Practicality increased across the three field tests

All four practicality indicators improved from one field test to the next (Fig. 2). In the preliminary test, teacher implementation rose from 75.0% in the first meeting to 82.6% in the second (mean 78.8%, good), while student activity rose from 61.1% to 65.7% (mean 63.4%, fair). The teacher rated the materials as practical (78%), and the 22 students also rated them as practical (77%). Observers noted that students struggled most with evaluation, inference, and the independent use of local wisdom references. Revision I therefore strengthened worksheet scaffolding and instructions, refined the cover, and added local examples closer to students' lives in Makassar.

In the main field test, teacher implementation averaged 83.9% (range 81.5–87.0%), with one school reaching the very good category (87.0%) and another just below it (85.9%). Student activity averaged 66.5% (63.0–72.2%). All six teachers rated the materials as highly practical (mean 83.0%), and the 176 students gave a mean of 80.0%. Revision II simplified teacher instructions, added more interactive activities, and made student instructions more child-friendly.

In the operational field test, teacher implementation averaged 89.9% (very good), with all ten schools in the very good category (86.9–94.0%). Student activity reached 88.6% (very good in nine of ten schools), 25.2 percentage points higher than in the preliminary test. Teacher responses averaged 89.1% and student responses 85.2%, with all ten teachers and all ten classes rating the materials as highly practical. Interview data were consistent with these figures. Teachers reported that the guide was detailed enough for first-time users of deep learning and that the worksheets, formative assessments, and module formed one coherent package, so no extra preparation was needed.

> "The materials are very easy to use, even for a teacher who is applying the deep learning approach for the first time. The teacher guide is very detailed and practical." (Teacher 2)

> "It's really easy to use. Sometimes I read and do the exercises by myself at home without waiting for the teacher's explanation, because the instructions are already clear." (Student, experimental class)

Fig. 2 shows the trajectory of the four indicators across the three stages. Student activity started lowest and changed little between the preliminary and main tests (63.4% to 66.5%), but rose steeply

after the second revision to 88.6%, a gain of 25.2 percentage points over the preliminary test that took it above the threshold for very good implementation. The other three indicators started close together (77–79%) and rose more gradually: teacher implementation by 11.1 points, teacher responses by 11.1 points, and student responses by 8.2 points. Overall, practicality rose after each revision. Because the stages also differed in schools, sample size, and the units taught (Unit 1, Unit 2, and Units 3–4, respectively), and no inferential test was applied to these stage-to-stage changes, the increases cannot be attributed to the revisions alone; the rise in student activity coincided mainly with the stronger scaffolding and clearer instructions introduced in Revision II, which also added interactive activities. One teacher also began sharing the materials with colleagues in neighboring schools.

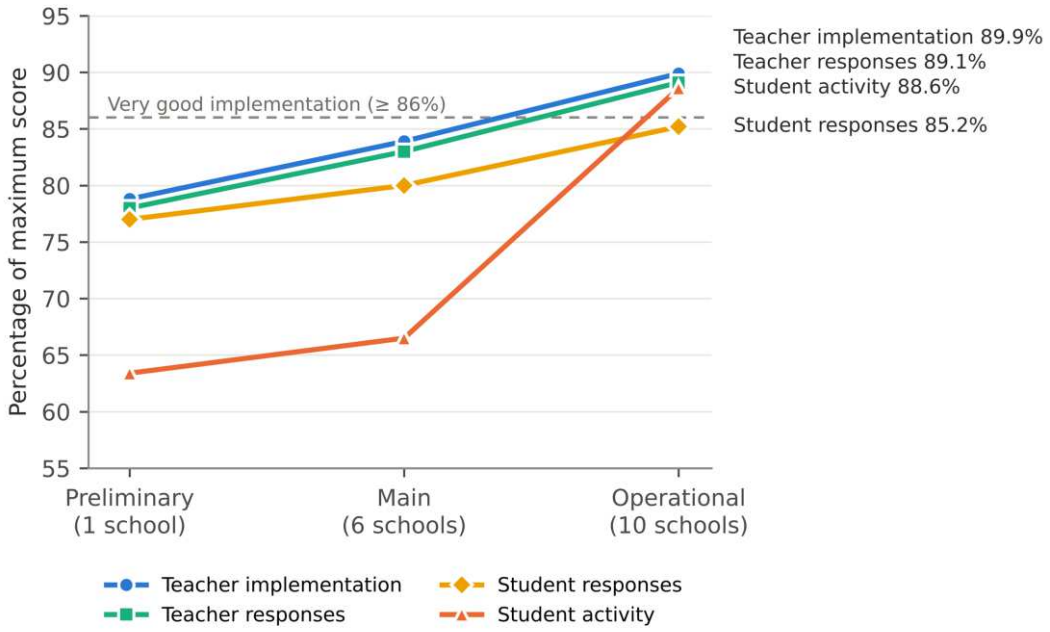


Fig. 2 Change in the four practicality indicators across the three field-test stages. The dashed line marks the threshold for very good implementation (≥86%).

Experimental classes scored higher than control classes in all schools and on all indicators

Critical thinking scores were higher in experimental than in control classes in all ten schools (Table 6). School means ranged from 79.04 to 83.62 in experimental classes and from 51.84 to 56.57 in control classes, a difference of 27.05–28.67 points. Averaged across the ten schools, the experimental mean was 81.73 and the control mean 54.14, a difference of 27.60 points. Scores were approximately normally distributed in most groups (Shapiro–Wilk $p > 0.05$ in 19 of 20 groups; Lilliefors-corrected Kolmogorov–Smirnov $p > 0.05$ in 17 of 20), and variances were homogeneous in nine schools (Levene $p = 0.26$–0.90); in SDN Kompleks IKIP ($p = 0.022$) Welch's test gave the same result ($t = 27.98$, $p < 0.001$). The independent-samples t-test was significant in every school ($t = 25.02$–34.64, $df = 41$–63, $p < 0.001$), and the effect sizes were very large (Cohen's $d = 7.00$–8.59), well beyond those usually observed for classroom interventions (see "Research limitations and future directions"). A two-way analysis of variance confirmed the group difference after accounting for school, $F(1, 572) = 8297.1$, $p < 0.001$, partial $\eta^2 = 0.94$, with no group × school interaction, $F(9, 563) = 0.33$, $p = 0.97$. The null hypothesis was therefore rejected in all ten schools. Given the posttest-only design with intact classes, these differences are interpreted as associations with the use of the materials rather than as precise estimates of their causal effect.

Table 6 Results of the independent-samples t-test on critical thinking in the operational field test.

School	n (E/C)	Exp. mean	Control mean	Diff.	t (df)	p	Cohen's d
SDN Mangkura III	22/21	80.85	53.60	27.25	25.02 (41)	< 0.001	7.63
SDI Pampang II	29/29	82.90	55.81	27.10	27.32 (56)	< 0.001	7.17
SDI Mariso II	30/30	83.62	56.57	27.05	28.48 (58)	< 0.001	7.35
SDI Bontoa	31/31	82.49	53.82	28.67	28.37 (60)	< 0.001	7.20
SDI Mangasa I	33/32	81.30	53.30	27.99	34.64 (63)	< 0.001	8.59
SDN Kaccia	31/32	81.38	53.39	27.99	29.72 (61)	< 0.001	7.49
SDN Sumanna	30/30	82.57	55.47	27.10	27.12 (58)	< 0.001	7.00
SDN Bawakaraeng I	28/28	80.71	52.82	27.90	29.10 (54)	< 0.001	7.78
SDN Lariang Bangi I	28/28	79.04	51.84	27.19	29.80 (54)	< 0.001	7.97
SDN Kompleks IKIP	30/30	82.48	54.77	27.72	27.98 (58)[a]	< 0.001	7.22
Total / mean of school means	292/291	81.73	54.14	27.60	—	< 0.001	7.00–8.59

Note: E = experimental class, C = control class; independent-samples t-test on individual student scores, $\alpha = 0.05$. [a] Levene's test $p = 0.022$; Welch's $t = 27.98$, $p < 0.001$. Data and analysis script: Supplementary Information S1 and S3.

The experimental advantage held for all six of Facione's indicators (Fig. 3). Control classes clustered in a narrow band of 50.3–58.1 points, whereas experimental classes reached 82.7–86.5 on five indicators, with the highest scores for self-regulation (86.5) and evaluation (86.4). Ordered by the size of the gap, inference showed the largest advantage (31.2 points), followed by explanation (30.2), analysis (28.9), self-regulation (28.8), and evaluation (28.4). Interpretation stood apart, with both the lowest experimental score (70.9) and the smallest gap (20.5 points). The mean of the six indicator gaps (28.0 points) is close to the overall difference between the groups. Observation and response data were collected only in the experimental classes. They show that these classes were highly engaged and that teachers and students judged the materials highly practical, but they do not by themselves provide a comparison with the control classes.

Table 7 brings together the test, observation, response, and validation data. Only the critical thinking test compares experimental and control classes. The observation and response data, which came from the experimental classes and partly from the teachers who taught them, show that the materials were implemented as intended and were well received; this supports the plausibility of the test results but does not independently confirm a causal interpretation.

Table 7 Summary of evidence from the test, observation, response, and validation data.

Data source	Instrument	Result	Conclusion
Critical thinking test	Essay test on Facione's six indicators (Aiken's V = 0.778)	Experimental > control in 10 of 10 schools; t = 25.02–34.64; p < 0.001	Significantly higher scores
Implementation observation	Teacher and student observation sheets (V = 0.833 and 0.837)	Teacher implementation 89.9%; student activity 88.6% (very good)	Implemented consistently
Teacher and student responses	50-item questionnaires (V = 0.738 and 0.758)	Teachers 89.1%; students 85.2% (highly practical)	Received very positively
Expert validation	Validation sheets for materials and module (V = 0.705 and 0.718)	All domains and aspects valid (V ≥ 0.63)	Content-valid product

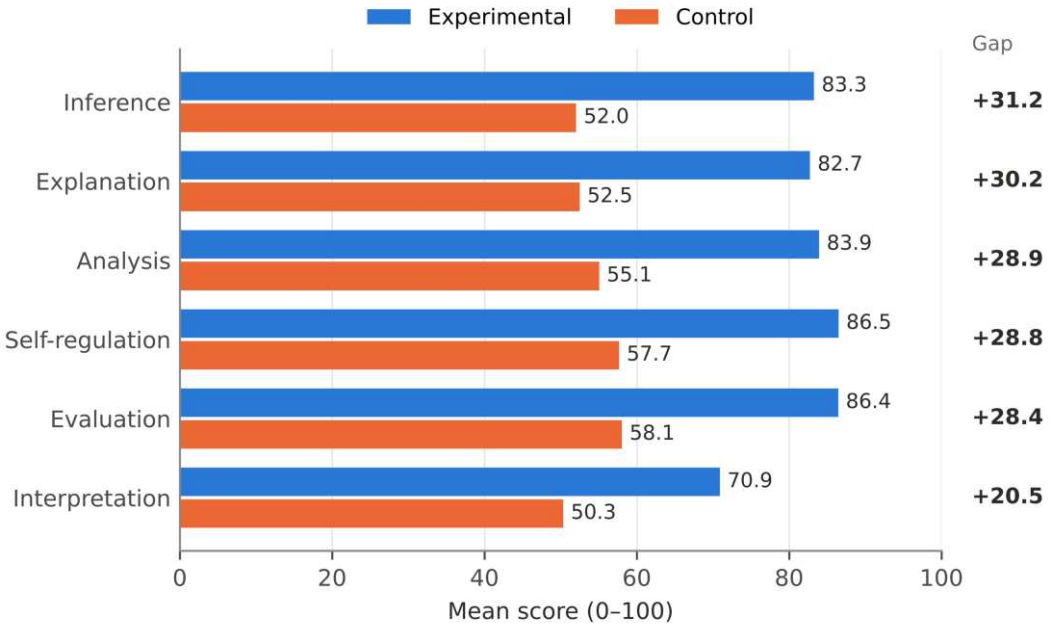


Fig. 3 Experimental and control class means on Facione's six critical thinking indicators in the operational field test, ordered by the size of the gap.

Discussion

The findings of this study collectively show that IPAS teaching materials combining the deep learning approach with Bugis-Makassar and Nusantara local wisdom can be developed to a valid standard, implemented practically by ordinary classroom teachers, and associated with substantially higher critical thinking scores. The Discussion is organized around the most significant findings of the study: why teachers needed ready-made materials rather than general encouragement; what the validity pattern says about an interdisciplinary product; why student engagement lagged behind teacher implementation; and how the pattern of critical thinking differences should be interpreted.

Design capacity as the main barrier for teachers

The needs analysis revealed a gap between valuing and enacting. Teachers agreed that local wisdom and deep learning matter, yet most rated their own understanding as limited and had rarely designed such lessons. This pattern suggests that the barrier is not attitude but design capacity, a finding consistent with reports that teachers lack time, facilities, and guidance to build culturally grounded materials on their own (Annisha, 2024; Burhan et al., 2024). The design response was therefore to embed pedagogy in the materials themselves: a fixed mindful–meaningful–joyful activity cycle, an explicit "knowledge bridge" between each local practice and the IPAS concept, and critical thinking questions written into every topic. Teachers' comments that no extra worksheets or assessments were needed indicate that this coherence reduced the planning burden that often prevents innovation from reaching classrooms.

Validity of an interdisciplinary product

The validity results show that the materials satisfied five demanding criteria at once: IPAS content, media and visual design, language, classroom practicality, and South Sulawesi local wisdom. Each domain was endorsed most strongly by the specialist in that field (0.857–0.917), and every domain mean fell within the valid range (0.692–0.719). This finding is in line with earlier studies reporting that local wisdom-based IPAS materials meet academic feasibility standards (Duratun & Rokhman, 2024; Salmia et al., 2024a), and it extends them by validating not only the materials but the full package of module, observation sheets, questionnaires, and critical thinking test. Expert review and classroom evidence complemented each other within the Borg and Gall cycle: validator comments guided the first revision, and field data guided the later ones (Borg & Gall, 1983; Salmia et al., 2024a).

Student engagement and the role of scaffolding

Practicality rose at every stage, but student activity lagged behind teacher implementation until the operational test (Fig. 2). In the preliminary and main tests, teachers already implemented the syntax well (78.8% and 83.9%), whereas student activity remained fair (63.4% and 66.5%), with the weakest performance on evaluation, inference, and the independent use of local wisdom sources. This gap is plausible: students accustomed to receiving information need time and structure before they can manage open-ended, higher-order tasks. The sharp rise to 88.6% after the second revision, which focused on worksheet scaffolding and child-friendly instructions, is consistent with the view that the support students received to carry out deep learning activities mattered more than the presence of the activities themselves, although the change in units and schools between stages means that this interpretation remains tentative. Students' reports that they could work through the materials at home without waiting for the teacher point in the same direction.

Interpreting the pattern of critical thinking differences

The effectiveness results were consistent across all ten schools and all six indicators (Table 6 and Fig. 3). From a constructivist perspective, the materials asked students to build concepts from familiar cultural experience and to negotiate meaning in groups, conditions that Piaget (1952) and Vygotsky (1978) regard as central to cognitive development. Linking new IPAS concepts to well-known practices such as *Pinisi* navigation or *Sasi* closures may also provide richer retrieval cues and deeper processing, as information-processing theory would predict (Atkinson & Shiffrin, 1968). The six Facione indicators map onto the higher-order levels of the revised Bloom taxonomy (Anderson &

Krathwohl, 2010), and collaborative tasks in which students observe and discuss local practices draw on social learning (Bandura, 1977). The largest differences were in inference and explanation, which may indicate that the repeated requirement to draw conclusions from evidence and to justify answers with reasons and local evidence was particularly productive; research on project and inquiry tasks similarly finds that articulating reasoning is a main route to critical thinking (Amani & Mkimbili, 2025; Wang, 2024). Interpretation showed the smallest difference and the lowest experimental score. Interpretation depends heavily on reading comprehension, and the preliminary study had noted that many students struggled with technical vocabulary in IPAS texts. Future versions should therefore strengthen guided reading of the local wisdom stimulus texts at the start of each lesson.

A notable feature of these results is their consistency. The difference between experimental and control classes was large and similar in every school (27.05–28.67 points, with no group × school interaction), across coastal and urban schools and across regular state and SD Inpres schools, which suggests that the association was not confined to a single context. Consistency across schools does not, however, rule out a source of bias common to every school, such as the close alignment of the test with the local wisdom content of the materials or pre-existing differences between experimental and control classes. The test results were also matched by very good implementation and highly positive responses from teachers and students (Table 7). These findings are consistent with earlier studies reporting that local wisdom-based materials improve elementary students' critical thinking (Duratun & Rokhman, 2024; Mulyani, 2025; Ni et al., 2024; Pristiwanti et al., 2024), and they extend this evidence to a larger sample of ten schools and to all six of Facione's indicators.

Local wisdom, sustainability, and design implications

The integration of local wisdom also extends the meaning of IPAS beyond cognitive outcomes. Many of the practices embedded in the materials, including *Sasi*, *Tana' Ulen*, *Lubuk Larangan*, *Smong*, and earthquake-resistant stilt houses, are community strategies for conserving resources and reducing disaster risk. Studying them allows students to connect ecosystems, natural resources, and hazards to responsible collective action, which aligns the materials with education for sustainability. Values such as *sipakatau* and *pattulung-tulungan* appeared, according to classroom observers, to support a culture of discussion and cooperation, consistent with the view that culturally responsive teaching strengthens both learning and identity (Alwi & Suarni, 2024; Gay, 2018; Ladson-Billings, 1995). These effects on character and identity were not measured, however, and remain a hypothesis for future work.

Taken together, these findings suggest several implications for both the design and the theoretical framing of culturally grounded deep learning materials in elementary education. First, deep learning principles should be translated into a consistent, named activity cycle that teachers can follow without additional training. Second, local wisdom should serve a function in the lesson (opening context, concept bridge, authentic problem, or object of reflection) rather than appear as decoration. Third, critical thinking should be designed in, with questions mapped to explicit indicators and assessed with a rubric. Fourth, students need graduated scaffolds, especially for interpretation, evaluation, and inference, before they can work independently. These principles respond directly to the gaps identified in the needs analysis and may guide similar development in other regions and subjects (Dewi & Suniasih, 2023; Khaerani & Utami, 2020; Salmia et al., 2024b; Semaranata et al., 2024; Wadi et al., 2023). The highly positive student responses and the enthusiasm observed during implementation also accord with humanistic views that learning flourishes when it is student-centered and meets students' needs for belonging, recognition, and self-actualization (Maslow, 1986; Rogers, 1961).

Research limitations and future directions

Despite these contributions, this study has several limitations that should be acknowledged. First, the operational field test used a quasi-experimental posttest-only control group design with intact classes that were not randomly assigned, and no pretest was administered. Differences between experimental and control classes may therefore partly reflect pre-existing differences in prior achievement, class composition, or teachers, and the results should be read as associations rather than as causal effects. Second, the effect sizes (Cohen's d = 7.00–8.59; partial $\eta^2 = 0.94$) are far larger than those typically reported for educational interventions. They are unlikely to represent the effect of the materials alone and probably also reflect the other factors described in this section, in particular the close alignment between the test and the experimental materials. Third, the critical thinking test was developed by the research team and built around local wisdom stimulus texts, a format that students in the experimental classes practised throughout the intervention but students in the control classes did not; the test may therefore favour the experimental condition. Its stimulus topics also did not fully coincide with the units taught in the operational stage, so it measures critical thinking in local wisdom-based IPAS contexts rather than mastery of the unit content. Fourth, each school contributed one experimental and one control class, so condition was confounded with class and teacher, and students were analysed as independent observations without accounting for their clustering in classes. The reported t-tests and analysis of variance therefore probably overstate statistical precision, and a multilevel analysis was not feasible with this design. Fifth, the validity of the instruments was established by expert judgement only; internal-consistency reliability, inter-rater agreement for the essay scoring, and inter-observer agreement for the observation sheets were not computed; in addition, inference and self-regulation were each measured by a single test item, so the indicator-level comparisons in Fig. 3 are less precise than the total score. Sixth, the practicality evidence relies on observation and on self-report by teachers and students who knew they were using new materials, so novelty and social desirability effects cannot be excluded; moreover, the stage-to-stage increases in practicality were not tested statistically and coincided with changes in schools, samples, and units. Seventh, the developers of the materials also conducted the evaluation, which may have introduced expectancy effects. Eighth, critical thinking was measured only once, at the end of the intervention, so retention and transfer were not examined. Ninth, schools were selected purposively from a single city, and the study was limited to fifth-grade IPAS in Makassar, so the findings cannot be generalised to other regions, grades, or subjects without further testing. Finally, the contribution of the materials to character and cultural identity, although observed informally during implementation, was not measured. Future research should therefore use randomised or pretest–posttest designs with more classes per condition and multilevel analysis, employ an independent critical thinking measure scored blind to condition, and report reliability and inter-rater agreement. It should also include delayed posttests, extend the materials to other grades, subjects, and regions with their own local wisdom, examine other competencies such as creativity, problem solving, collaboration, and scientific literacy, and develop the materials in digital or interactive formats.

Conclusions

This research and development study indicates that IPAS teaching materials integrating the deep learning approach with Bugis-Makassar and Nusantara local wisdom can be developed through the full Borg and Gall cycle into a valid and practical product that is associated with substantially higher critical thinking scores. The final product comprises four units and 12 topics in which 20 local wisdom practices serve as context, conceptual bridge, authentic problem, and object of reflection, supported by a teacher module, worksheets, a critical thinking test, and rubrics. Expert review rated

the materials and instruments valid to highly valid (Aiken's V = 0.705–0.837). Practicality increased at each field-test stage and reached the highest categories in the operational test, with teacher implementation at 89.9%, student activity at 88.6%, and teacher and student responses at 89.1% and 85.2%. Experimental classes scored higher than control classes in all ten schools and on all six of Facione's indicators, with the largest advantage in inference and the smallest in interpretation. These results suggest that culturally grounded deep learning materials are a feasible and promising way to support elementary students' critical thinking while keeping learning connected to their communities and environment. Because the effectiveness evidence comes from a posttest-only comparison of intact classes using a researcher-developed test, randomised or pretest–posttest studies with independent measures are needed before firm causal claims can be made.

Acknowledgments The authors thank the principals, fifth-grade teachers, and students of the participating elementary schools in Makassar, and the five expert validators.

Funding No funding was received for conducting this study.

Author contributions Hasan Hasan contributed to conceptualization, methodology, product development, investigation, formal analysis, and visualization, and drafted the manuscript. Nursalam Nursalam contributed to conceptualization, methodology, supervision, and manuscript review and editing. Agustan Syamsuddin contributed to conceptualization, methodology, supervision, and manuscript review and editing. All authors have read and agreed to the published version of the manuscript.

Declarations

Data availability The data, instruments and code supporting this study are openly available in the figshare repository at https://doi.org/10.6084/m9.figshare.34868250 and are also provided as Supplementary Information with this article. The shared materials comprise: (1) anonymised item-level critical thinking test scores for all 583 students (292 experimental and 291 control) in the ten schools of the operational field test; (2) all 1,745 ratings given by the five expert validators to the teaching materials, the teaching module and six research instruments (the two response questionnaires, the two observation sheets, the critical thinking test and the interview guide), from which Aiken's V was calculated; (3) aggregated responses to the teachers' needs-analysis questionnaire (n = 15); (4) teacher implementation, student activity, and teacher and student response scores for the three field-test stages, by school, meeting and class (item-level observation and questionnaire responses are not included); (5) the research instruments in the original Indonesian, namely the needs-analysis interview questions and questionnaire, the 25-question interview guide with its validation sheets, the 50-item teacher and student response questionnaires, the blueprints and rating scales of all instruments, the expert validation sheets for the questionnaires, the observation sheets and the test, and the full critical thinking test with its answer key and analytic rubric (the full observation sheets are available from the corresponding author on request); (6) a codebook defining every variable, its coding and the transformations applied; and (7) Python scripts that reproduce all reported analyses and Figs. 2 and 3. Students are identified only by codes, and no names or other personal identifiers are included. Audio recordings and full transcripts of interviews and focus group discussions are not shared publicly because they could identify teachers and students in a small number of named schools and participants were assured of confidentiality; de-identified excerpts are available from the corresponding author on reasonable request. Research permits and signed expert validation statements contain personal identifiers and have been provided to the editors for the purpose of peer review.

Competing interests The authors declare no competing interests.

Ethics approval and consent to participate This study involved human participants. Ethical approval was granted by the Institutional Review Board (IRB) of the Institute for Research, Development, and Community Service (Lembaga Penelitian, Pengembangan dan Pengabdian kepada Masyarakat [LP3M]), Universitas Muhammadiyah Makassar. All procedures performed in this study were conducted in accordance with applicable ethical standards and the principles of the Declaration of Helsinki (Approval No. 109/LP3M/05/C.4-VIII/XI/1447/2025).

Informed consent Informed consent was obtained from all individual participants included in the study prior to their participation. For the participating students, who were minors, informed consent was obtained from their parents or guardians, and the students gave their assent. Participation was voluntary, and participants were informed about the purpose of the research and the confidentiality of their responses.

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