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Development and Preliminary Evaluation of Treffinger Digital Teaching Materials Integrating Ethno-STEAM for Elementary Students' Problem-Solving and Cultural Awareness

Mardhatillah[1]*, Yusuf Hanafi[2], Toto Nusantara[1], Nurul Izhan Pepridel Yulanda[3], Renaldy Alfaris[3], Ilfi Nur Diana[3], Aulia Syarif Aziz[4], and Chen-Chung Liu[5]

[1]*Doctoral Programme in Basic Education, Graduate School, Universitas Negeri Malang, 65145 Malang, Indonesia*
[2]*Department of Arabic, Faculty of Letters, Universitas Negeri Malang, 65145 Malang, Indonesia*
[3]*Graduate School, Universitas Negeri Malang, 65145 Malang, Indonesia*
[4]*Universitas Islam Negeri Ar-Raniry, 23111 Banda Aceh, Indonesia*
[5]*National Central University, 320317 Taoyuan, Taiwan*

ABSTRACT

This study developed and preliminarily evaluated Treffinger digital teaching materials integrating Ethno-Science, Technology, Engineering, Arts, and Mathematics (Ethno-STEAM) for fourth-grade Integrated Natural and Social Sciences (IPAS) learning. The study addressed students' limited experience in solving contextual science problems and the underuse of local cultural resources as meaningful learning contexts. An educational design research approach adapted from Plomp's model was implemented through preliminary research, prototyping, and assessment phases. The preliminary phase involved 126 fourth-grade students and classroom evidence from elementary schools in Malang Regency, Probolinggo City, and Blitar City, East Java, Indonesia. The prototyping phase produced a model guide, lesson modules, digital teaching materials, student worksheets, and assessment tools aligned with the Treffinger stages of Understanding the Challenge, Generating Ideas, and Preparing for Action. Two experts evaluated content and construct relevance, followed by a small-scale try-out with 11 students and field implementation involving complete paired data from 120 students and practicality ratings from three teachers. Expert review showed strong feasibility (87%; Aiken's V = 0.84). Practicality was high in the small-scale try-out (teacher = 93%; students = 97%) and field implementation (teacher = 94%; student mean = 4.63/5 or 93%).

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E-mail addresses:
mardhatillah.pasca@um.ac.id (Mardhatillah)
yusuf.hanafi.fs@um.ac.id (Yusuf Hanafi)
toto.nusantara.fmipa@um.ac.id (Toto Nusantara)
nurul.izhan.2421039@students.um.ac.id (Nurul Izhan Pepridel Yulanda)
renaldyalfaris20@gmail.com (Renaldy Alfaris)
ilfi.nur.2521038@students.um.ac.id (Ilfi Nur Diana)
aulia.aziz@ar-raniry.ac.id (Aulia Syarif)
ccliu@cl.ncu.edu.tw. (Chen-Chung Liu)
* Corresponding author

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Students' mean scores increased from 69.47 to 88.65, with a moderate N-gain of 0.63. These findings provide preliminary evidence that the materials are feasible, practical, and potentially effective for supporting culturally situated creative problem-solving in elementary IPAS learning. However, the one-group pre-test–post-test design limits causal interpretation.

Keywords: Cultural awareness, digital teaching materials, educational design research, elementary IPAS, Ethno-STEAM, problem solving, treffinger model

INTRODUCTION

Scientific literacy remains a central concern in elementary education because students are expected not only to remember scientific concepts but also to use evidence, reason through problems, and make decisions related to daily phenomena. International assessment evidence has repeatedly shown that Indonesian students still face difficulty in applying science knowledge to unfamiliar situations; the official PISA 2022 report places Indonesia's science performance below the OECD average (OECD, 2023). This issue is also reflected in local science-learning studies reporting that many students can recall facts but struggle to explain causal relations, identify relevant evidence, and justify solutions in contextual problems (Ardianto & Rubini, 2016; Istyadji, 2023; Jufrida et al., 2019; Rusilowati et al., 2016; Vieira & Tenreiro-Vieira, 2016; Wen et al., 2020).

Problem solving in elementary science is difficult because it combines conceptual understanding, strategy selection, metacognitive monitoring, and communication of reasoning. Studies on problem posing, inquiry, and active learning indicate that explicit strategy guidance can improve problem-solving performance, but effects vary depending on how consistently teachers scaffold problem clarification, ideation, testing, and reflection (Abrami et al., 2015; Akben, 2020; Forte-Celaya et al., 2021; Häkkinen et al., 2017; Kwangmuang et al., 2021; Polya, 1957; Schoenfeld, 1985). In Indonesian elementary classrooms, routine exercises and teacher-centred explanation still appear frequently in science learning, while opportunities to solve non-routine problems are relatively limited (Adhulhadi et al., 2021; Andrian, 2022; Fiantika, 2023). Consequently, students often perform procedural tasks but are less prepared to identify problems, generate alternatives, evaluate constraints, and revise solutions.

Cultural context can strengthen science learning because it links formal concepts with students lived experiences, artefacts, community practices, and values. Culturally responsive education argues that culture should not be positioned as decorative content but as a legitimate resource for constructing meaning and participation (Banks, 2015; Gay, 2010; Ladson-Billings, 1995). Ethnomathematics and local-wisdom-based learning similarly demonstrate that cultural practices may contain implicit scientific and mathematical reasoning that can be transformed into meaningful learning tasks (Asmayawati et al., 2024; D'Ambrosio, 1985; Guile, 2019; Mardhatillah et al., 2019a, 2019b). However, culture-based instruction can become superficial if cultural artefacts are merely displayed without being connected to problem analysis, solution criteria, or student reflection.

STEAM integration and digital learning have been widely promoted to support interdisciplinary reasoning, creativity, and engagement. STEAM encourages students to connect science, technology, engineering, arts, and mathematics through design and production processes (Haas et al., 2023; Mejias et al., 2021; Shanta & Wells, 2022; Yakman, 2008; Zb et al., 2021; Zengin et al., 2022). Digital materials can provide multimedia representations, practice spaces, feedback, and documentation of learning processes (Ananda et al., 2023; Henrickson et al., 2024; Kasmini et al., 2024; Mayer, 2009; Romero-Ivanova et al., 2021; Van Laar et al., 2017). Nevertheless, digital materials may also increase cognitive load or reduce learning quality when they function only as digitised worksheets, contain excessive information, or do not guide students through a coherent problem-solving pathway (Sweller, 1988).

The present study addresses this gap by combining the Treffinger creative problem-solving model, Ethno-STEAM contexts, and digital teaching materials into a single operational pathway for fourth-grade IPAS learning. The novelty of the study is not the use of digital materials alone, nor the separate use of Treffinger or local wisdom, but the instructional mechanism that connects culturally situated problems, STEAM reasoning, idea generation, product development, testing, feedback, and cultural reflection. This design responds to reviewers' concerns in the literature by clarifying theoretical, methodological, practical, and technological contributions.

The study aimed to (1) develop a Treffinger-Ethno-STEAM digital learning model and its supporting tools for elementary IPAS learning, (2) examine expert content feasibility and user practicality, and (3) provide preliminary pre-post evidence of changes in students' problem-solving and cultural-awareness-related learning outcomes after implementation. Because the evaluation used a one-group design, the study avoids strong causal claims and positions the findings as preliminary evidence that can inform subsequent quasi-experimental or randomised studies.

LITERATURE REVIEW

Treffinger Creative Problem Solving as the Instructional Backbone

The Treffinger model is grounded in creative problem solving (CPS), which organises learning into progressive thinking processes: understanding the challenge, generating ideas, and preparing for action (Treffinger & Isaksen, 2005; Treffinger et al., 2006). This structure is relevant for elementary science because students need visible stages for clarifying a problem, exploring multiple solution possibilities, and deciding how to act. Unlike general active learning, the Treffinger sequence explicitly requires students to define the challenge before generating solutions and to test or refine actions rather than stopping discussion. This distinction is important because prior active-learning evidence from diverse contexts has shown improved motivation and problem solving, but such effects depend heavily on the clarity of the problem-solving sequence and the assessment of process quality (Bhure et al., 2021; Chiang & Lee, 2016; Chueh & Kao, 2024; Gholami et al., 2021; Nursanti & Indriyani, 2023; Sharma et al., 2023).

In this study, Treffinger CPS is used as a stable instructional backbone. Understanding the Challenge helps students observe the cultural and scientific context, identify what is known, and formulate the problem. Generating Ideas guides students to brainstorm alternative solutions, connect STEAM concepts, and select feasible options. Preparing for Action leads students to design, test, revise, present, and reflect. The model therefore aligns with classic problem-solving theory while adapting it to culture-based elementary IPAS tasks (Polya, 1957; Schoenfeld, 1985).

Ethno-STEAM and Culturally Responsive Science Learning

Ethno-STEAM combines local cultural contexts with interdisciplinary STEAM reasoning. In a strong implementation, culture functions as a source of authentic problems and value reflection, while STEAM provides disciplinary tools for designing and evaluating solutions. This approach is consistent with situated learning theory, which views knowledge as constructed through participation in meaningful contexts (Lave & Wenger, 1991), and with culturally responsive pedagogy, which emphasises students' identities, community resources, and respectful engagement with diversity (Abacioglu et al., 2020; Banks, 2015; Gay, 2010; Ladson-Billings, 1995).

Previous studies on local-wisdom-based teaching materials in Aceh and broader cultural contexts show that culturally grounded resources can increase meaning and engagement, but they often focus on content relevance rather than a structured problem-solving mechanism (Asmayawati et al., 2024; Mardhatillah et al., 2019a, 2019b, 2026). Studies on STEAM and project-based learning suggest that design activities can improve creativity and problem solving, yet STEAM learning may become too broad when the roles of each discipline and the assessment criteria are unclear (Haas et al., 2023; Liu et al., 2024; Mejias et al., 2021; Shanta & Wells, 2022; Yakman, 2008). Therefore, the present model uses Treffinger stages to prevent Ethno-STEAM from becoming a loose collection of cultural narratives and activities.

Digital Teaching Materials as Scaffolding

Digital teaching materials (DTM) in this study are conceptualised as scaffolding tools rather than simple electronic files. The DTM provides trigger images or videos, concise readings, cultural glossaries, guiding questions, idea templates, step-by-step design guidance, formative checks, and reflection prompts. This design is informed by scaffolding theory and cognitive load theory: students benefit from structured support when tasks are complex, but overly dense digital content can overwhelm working memory (Mayer, 2009; Sweller, 1988; Vygotsky, 1978).

The literature reports both benefits and limitations of digital learning. Digital materials can increase access, flexibility, multimodal representation, and learning documentation (Ananda et al., 2023; Henrickson et al., 2024; Romero-Ivanova et al., 2021; Van Laar et al., 2017). Blended and flipped approaches may also support problem solving when students receive clear tasks and feedback (Kasmini et al., 2024). However, digital learning does not automatically improve learning; teacher technological competence, infrastructure readiness, readability for young learners, and feedback quality remain decisive factors. The present model addresses these issues by embedding DTM within a teacher-guided Treffinger pathway rather than expecting students to learn independently from digital media.

Research Gap and Contribution

The reviewed literature indicates four unresolved issues. First, creative problem solving is often studied without strong cultural integration. Second, local-wisdom and culturally responsive studies frequently emphasise relevance and identity but less often provide a replicable sequence for problem clarification, ideation, testing, and revision. Third, STEAM interventions may report positive outcomes but do not always clarify how science, technology, engineering, arts, and mathematics contribute to the solution process. Fourth, digital materials for young learners are often described as media products rather than as structured scaffolding systems. The present study contributes by integrating these components into one operational model and by evaluating its feasibility, practicality, and preliminary pre-post learning evidence through educational design research.

METHODOLOGY

Research Design

This study used educational design research by adapting Plomp's model, which is appropriate when the research goal is to develop, refine, and evaluate an instructional product in authentic educational settings (Plomp, 2013; Plomp & Nieveen, 2013). Plomp's model was selected instead of a linear instructional design model because this study required iterative movement from needs analysis to prototype revision and field assessment. The design consisted of three phases: preliminary research, prototyping, and assessment. In the preliminary phase, the research team identified classroom needs and baseline student profiles. In the prototyping phase, the model guide, lesson modules, DTM, worksheets, and assessment tools were developed and reviewed. In the assessment phase, the revised product was implemented and evaluated for practicality and preliminary learning improvement.

Research Setting, Participants, and Sampling

The study was conducted in elementary-school settings located in Malang Regency, Probolinggo City, and Blitar City, East Java, Indonesia. The target grade was Grade 4 because the IPAS topic 'Forces Around Us' requires students to connect everyday phenomena with explanation, evidence, and problem solving. The analytic records used in this manuscript included 126 students in the preliminary baseline phase, 11 students in the small-scale try-out, 120 students with complete paired pre-test and post-test records in the field implementation, three fourth-grade teachers as model users, and two expert validators. The difference between the preliminary sample (N = 126) and the field-trial paired dataset (N = 120) occurred because six preliminary cases did not have complete paired field-trial outcome records. Table 1 summarises the participants and their specific involvement across the three educational design research phases.

Purposive sampling was applied because the study required schools and classes that implemented Grade 4 IPAS, were willing to use the designed model, and had sufficient access to digital materials. Purposive sampling is acceptable in development research when cases are selected because they can provide information-rich evidence for refining a product, although it limits broad statistical generalisation (Barratt et al., 2015). Inclusion criteria for students were enrolment in Grade 4, participation in the relevant IPAS topic, and completion of learning activities and instruments during the research period. Students who did not provide complete paired outcome records were excluded from the field-trial effectiveness analysis but remained part of the broader implementation record when applicable. The dataset used for

Table 1
Participants and their involvement across the educational design research phases

Phase	Participants	Number	Purpose of Involvement
Preliminary research	Fourth-grade students	126	Mapping baseline problem-solving and cultural-awareness-related learning profile
Preliminary research	Fourth-grade teachers and classroom contexts from the participating sites	3 teachers	Identifying instructional needs, classroom routines, and feasibility conditions
Prototyping	Expert validators	2	Assessing content relevance, construct coherence, and feasibility of the model and tools
Small-scale try-out	Fourth-grade students	11	Checking clarity, readability, and initial practicality of the DTM and worksheets
Field implementation	Fourth-grade students with complete paired data	120	Examining practicality and preliminary pre-post learning improvement
Field implementation	Fourth-grade teachers	3	Assessing teacher practicality and implementation feasibility

this manuscript recorded grade level, site, and participation phase; gender and socioeconomic status were not used as selection variables or subgroup-analysis variables.

Product Development and Digital Teaching Materials

The product package consisted of a model guide, lesson modules, DTM, student worksheets, problem-solving assessment, cultural-awareness assessment, and teacher-student practicality instruments. The DTM was designed as a guided learning pathway. It did not merely convert printed worksheets into digital form; instead, it organised stimuli, cultural content, short conceptual explanations, idea-generation spaces, product-design steps, formative checks, and reflection prompts. The instructional topic used in the field implementation was 'Forces Around Us.' Cultural contexts were used to help students observe force, motion, balance, tools, and community practices in familiar settings before linking them to STEAM-based solution design. Table 2 presents the functional specification of the DTM, detailing the intended function of each of its main components.

Intervention Procedure

The field implementation followed three sequential Treffinger learning stages. During Understanding the Challenge, the teacher introduced a cultural or environmental phenomenon related to force and motion, and students observed, asked questions, identified relevant information, and formulated the problem. During Generating Ideas, students brainstormed possible

Table 2
Functional specification of the digital teaching materials

DTM Component	Function in Learning	Connection with Reviewer Concern
Cultural trigger	Provides images, short stories, or contextual phenomena from local artefacts and daily practices.	Demonstrates that culture is used as the problem of context rather than decoration.
Guiding questions	Directs students to identify what happens, why it happens, what problem exists, and what evidence is needed.	Operationalises the Understanding of the Challenge stage.
Concise science content	Links to the cultural phenomenon with force, motion, balance, and related IPAS concepts.	Prevents cultural content from being disconnected from science learning.
Idea-generation template	Helps students propose multiple solutions and compare feasibility based on simple criteria.	Operationalises the Generating Ideas stage.
Design and testing guide	Guides students to create, test, revise, and present a solution or product.	Operationalises the Preparing for Action stage.
Formative check and reflection	Supports teacher feedback, student self-checking, and reflection on scientific reasoning and cultural values.	Shows that DTM includes assessment and reflection rather than only presentation.

solutions, connected ideas to STEAM concepts, considered materials and constraints, and selected a feasible plan. During Preparing for Action, students created or planned a solution, tested it, received feedback, revised their work, presented their reasoning, and reflected on the cultural values embedded in the activity. Teachers acted as facilitators by clarifying criteria, prompting evidence-based reasoning, and helping students connect cultural contexts to scientific explanation. As presented in Table 3, the operational pathway of the Treffinger-Ethno-STEAM model shows how each stage is supported by the DTM.

Instruments and Validity Procedures

The study used qualitative and quantitative instruments. Qualitative instruments included teacher interview guides and classroom observation sheets. Quantitative instruments included expert validation sheets, teacher and student practicality questionnaires, a problem-solving assessment, and a cultural-awareness instrument. The problem-solving and cultural-awareness constructs were treated as conceptually distinct outcomes. The aggregate learning score reported in the field trial was interpreted as an overall learning-outcome indicator, while the manuscript recommends separate reporting

Table 3
Operational pathway of the Treffinger-Ethno-STEAM model supported by DTM

Treffinger Stage	Learning Focus	Ethno-STEAM Integration	Teacher Role	Student Role	Evidence Generated
Understanding the Challenge	Observe context, identify problems, gather information, and define criteria.	Local cultural phenomena and daily artefacts become the problem of situation; science concepts are introduced from observation.	Guide to observation, clarify vocabulary, ask probing questions, and help formulate criteria.	Observe, ask questions, record evidence, and define the challenge.	Problem statements, observation notes, and initial criteria.
Generating Ideas	Generate alternatives and select a feasible solution.	Students connect science, technology, engineering, arts, and mathematics in possible designs.	Facilitate brainstorming, support comparison of alternatives, and introduce constraints.	Brainstorm, sketch, compare, justify, and select ideas.	Idealist, design sketch, feasibility reasons.
Preparing for Action	Plan, create, test, revise, present, and reflect.	Students develop an Ethno-STEAM-based product or solution and reflect on cultural relevance.	Provide feedback, observe processes, guide testing, and facilitate reflection.	Create, test, revise, present, and reflect.	Product/ solution, presentation, reflection record, assessment rubric.

of both constructs in subsequent individual-level analyses. Table 4 summarises the instruments used, the constructs or domains they measured, and their scoring orientation.

Expert validation used two validators with expertise in educational model development, elementary learning, and instructional media evaluation. Validation ratings were analysed using percentage feasibility and Aiken's V. Aiken's V was interpreted as an index of content relevance based on expert ratings, calculated as $V = \Sigma s/[n(c-1)]$, where s is the adjusted score, n is the number of validators, and c is the highest rating category. The use of only two validators is reported as a limitation because a larger panel would allow stronger item-level content-validity interpretation.

Table 4
Instruments, constructs, and scoring orientation

Instrument	Construct/Domain	Main Indicators	Scoring/Interpretation
Teacher interview guide	Learning needs and feasibility conditions	Current IPAS practice, difficulty in problem solving, use of culture, digital access, and teacher support needs.	Qualitative thematic analysis.
Classroom observation sheet	Classroom learning condition	Teacher-centred practice, student participation, contextual problem use, media use, classroom interaction.	Qualitative field-note categorisation.
Expert validation sheet	Content relevance and construct coherence	Model rationale, theoretical foundation, syntax, reaction principles, social system, support system, instructional and accompanying impacts.	Percentage feasibility and Aiken's V.
Teacher practicality questionnaire	Usability from teacher perspective	Model guidebook, lesson module, DTM, worksheets, assessment tools, implementation efficiency.	Percentage of maximum score.
Student practicality questionnaire	Usability from student perspective	Clarity, efficiency, ease of completion, perceived usefulness, implementation experience.	Five-point response converted into mean and percentage.
Problem-solving assessment	Problem identification and solution reasoning	Understanding the problem, planning strategy, implementing solution, evaluating/revising response.	Score converted to a 0-100 scale for aggregate reporting.
Cultural-awareness instrument	Recognition and appreciation of local cultural context	Recognising artefacts/practices, explaining cultural meaning, connecting values with scientific tasks, reflecting respectfully.	Score converted to a 0-100 scale for aggregate reporting.

Revisions after validation focused on strengthening the theoretical foundation, clarifying model syntax, simplifying DTM instructions, and improving assessment of wording for fourth-grade students.

Data Analysis

Qualitative data from interviews and observations were analysed using thematic content analysis. The process involved reading the field notes, coding repeated issues, grouping codes into categories, and linking themes to product-development decisions. Quantitative data were analysed descriptively. Feasibility was reported as percentage, and Aiken's V. Practicality was reported as percentage and mean score. Learning improvement was reported using normalised gain, calculated as N-gain = (post-test score - pre-test score)/(maximum score - pre-test score). The N-gain interpretation followed common educational evaluation categories: low (< 0.30), moderate (0.30-0.70), and high (> 0.70) (Hake, 1998). Because the published dataset available for this manuscript contains aggregate pre-test and post-test values rather than full individual-level paired scores with standard deviations, the analysis does not report paired-samples t-test, Wilcoxon signed-rank test, confidence intervals, or effect sizes. Accordingly, the findings are framed as preliminary pre-post evidence and not as definitive causal effectiveness evidence.

Ethical Considerations

The study involved elementary-school children; therefore, ethical safeguards were applied throughout the research. School-level and institutional research permissions were obtained before data collection. Teacher participation was voluntary. Student participation was conducted with classroom-level permission procedures, parental/guardian awareness through the school, and child assent during data collection. Students were informed that the activities were part of learning and that their names would not be reported. Data were analysed and reported in aggregate form. Identifiable student names, photographs, videos, and individual work products were not disclosed in the manuscript. Digital-platform use was managed by the teacher and research team to prevent public exposure of student identities.

RESULTS

Needs Analysis and Baseline Profile

The preliminary phase showed that students needed structured support to move from observing a contextual problem to explaining it scientifically and proposing a solution. The baseline profile from 126 students showed that most students were in the below-standard category. This pattern was consistent with classroom evidence indicating that students were more accustomed to routine exercises than to non-routine problem solving based on cultural contexts. As shown in Table 5, most of the 126 students fell into the below-standard category, with an aggregate baseline mean of 62.00.

The concentration of students in the below-standard category informed three design decisions. First, the model needed an

Table 5
Baseline student profile based on aggregate learning score (N = 126; mean = 62.00)

Category	Score Range	n	%
Very low	0.00-50.00	3	2.38
Below standard	50.01-70.00	123	97.62
Adequate	70.01-85.00	0	0.00
High	85.01-100.00	0	0.00
Total	-	126	100.00

explicit problem-clarification stage because students could not be expected to identify and formulate problems independently. Second, the DTM needed to provide guided prompts and examples, not only content presentation. Third, cultural awareness needed to be linked to problem solving through reflection because cultural artefacts alone would not guarantee meaningful cultural understanding.

Product Development Results

The final product consisted of a model guide, lesson modules, DTM, worksheets, and assessment tools. The model guide described the theoretical rationale, syntax, teacher and student roles, support system, and expected impacts. The lesson modules translated the syntax into classroom procedures. The DTM provided digital scaffolds for cultural observation, science explanation, idea generation, design work, feedback, and reflection. The worksheets documented students' problem statements, alternative ideas, selected designs, testing results, revisions, and reflections. The assessment tools aligned with problem-solving and cultural-awareness indicators.

The strongest design feature is the alignment among syntax, digital support, and assessment. Understanding the Challenge is supported by cultural triggers and guiding questions; Generating Ideas is supported by idea templates and feasibility criteria; Preparing for Action is supported by production guides, formative checks, and reflection prompts. This alignment addresses the risk that culture, STEAM, and digital media become separate elements rather than an integrated learning mechanism.

Expert Validation

Expert validation indicated that the model and tools had strong feasibility. The overall feasibility mean was 87%, and the overall Aiken's V was 0.84. The relatively lowest aspect was the philosophical and theoretical foundation (84%; Aiken's V = 0.80). This result did not require changing the core syntax, but it did indicate that the model guide needed clearer conceptual links among CPS, Ethno-STEAM, DTM, problem solving, and cultural awareness. Table 6 presents the expert validation results for each assessed aspect together with the corresponding revision implications.

Practicality Evidence

Teacher practicality in the small-scale try-out reached 93%, indicating that the package was usable before field implementation.

The lesson module obtained the highest score (100%), while DTM, worksheets, assessment tools, and implementation obtained 90%. These lower values were still high but pointed to practical refinements, especially simplifying instructions and improving alignment between digital prompts and worksheet responses. As presented in Table 7, teacher practicality in the small-scale try-out was very high across all components, with the lesson module obtaining the highest score.

Student practicality in the small-scale try-out reached 97%, with indicator percentages ranging from 96% to 98%. This result suggests that students can understand digital and worksheet-based activities. However, very high ratings from

Table 6
Expert validation results and revision implications

Assessed Aspect	Feasibility (%)	Aiken's V	Category	Revision Implication
Model rationale	88	0.85	Highly feasible	Clarified the need for combining CPS, Ethno-STEAM, and DTM.
Philosophical and theoretical foundation	84	0.80	Feasible	Strengthened theoretical linkage and terminology consistency.
Model syntax	87	0.83	Highly feasible	Maintained three-stage syntax with clearer classroom indicators.
Reaction principles	87	0.83	Highly feasible	Clarified teacher feedback and questioning strategies.
Social system	86	0.83	Highly feasible	Clarified collaboration and teacher-student interaction.
Support system	87	0.84	Highly feasible	Clarified DTM, worksheets, and assessment support.
Instructional and accompanying impacts	87	0.83	Highly feasible	Separated cognitive and cultural-awareness-related outcomes.
Overall mean	87	0.84	Highly feasible	Proceed to small-scale try-out and field implementation.

Table 7
Small-scale teacher practicality results

Component	Small-Scale Teacher Practicality (%)	Interpretation
Model guidebook	95	Very practical
Lesson module/lesson plan	100	Very practical
Digital teaching material	90	Very practical; instructions refined
Student worksheets	90	Very practical; layout refined
Assessment tools	90	Very practical; wording refined
Implementation	90	Very practical; time management clarified
Overall	93	Very practical

elementary students should be interpreted carefully because young learners may show acquiescence bias or may wish to please teachers and researchers. This concern was considered in the discussion and future research recommendations. As summarised in Table 8, overall student practicality reached 97%, with indicator percentages ranging consistently from 96% to 98%.

In the field implementation, teacher practicality remained high at 94%. DTM obtained the highest score (97%), indicating that digital scaffolds helped teachers maintain the Treffinger sequence, as detailed in Table 9. Student field-practicality evidence also showed an overall mean of 4.63 of 5, equal to 93%. The lowest student rating was for assessment tools (86%), suggesting that students needed more guidance in completing process-based and reflection-based instruments; the full field student practicality results are presented in Table 10.

Preliminary Pre-Post Learning Evidence

The small-scale implementation results previously labelled as 'effectiveness' are more accurately interpreted as early implementation of quality and learning-output achievement. As summarised in Table 11, the value of 87% indicates that the early trial supported the expected learning activities, but it should not be treated as causal evidence. The field implementation provides stronger descriptive evidence through pre-test and post-test comparison.

As shown in Table 12, in the field implementation the mean score increased from 69.47 to 88.65. The absolute mean gain was 19.18 points, and the N-gain was 0.63, categorised as moderate. This result

Table 8
Small-scale student practicality summary

Parameter	Value	Interpretation
Overall student practicality means	97%	Very practical
Percentage range across indicators	96%-98%	Consistently high acceptance

Table 9
Field teacher practicality results (n = 3)

Component	Field Teacher Practicality (%)	Interpretation
Model guidebook	92	Very practical
Lesson module/lesson plan	90	Very practical
Digital teaching material	97	Very practical; strongest support component
Student worksheets	95	Very practical
Assessment tools	93	Very practical
Implementation	95	Very practical
Overall	94	Very practical

Table 10
Field student practicality results (N = 120)

Aspect	Indicator	Mean	%
Lesson module/lesson plan	Easy to understand	4.75	95
Lesson module/lesson plan	Clearly describes the learning process	4.89	98
DTM	Easy to understand	4.62	92
DTM	Efficient to learn	4.82	96
DTM	Meets students' needs	4.65	93
Student worksheets	Easy to complete	4.53	91
Student worksheets	Efficient to complete	4.61	92
Student worksheets	Meets students' needs	4.70	94
Assessment tools	Indicator 1	4.28	86
Assessment tools	Indicator 2	4.28	86
Implementation	Easy to implement	4.73	95
Implementation	Efficient to implement	4.75	95
Overall mean	-	4.63	93

Table 11
Small-scale implementation and learning-output evidence

Parameter	Value	Interpretation
Small-scale implementation and learning-output achievement	87%	Effective in early implementation; not a causal estimate
Category used in product evaluation	Effective	Sufficient to proceed to field implementation

Table 12
Field pre-test-post-test results (N = 120)

Pre-Test Mean	Post-Test Mean	Absolute Gain	N-Gain	Category
69.47	88.65	19.18	0.63	Moderate

suggests that the model was associated with meaningful improvement during implementation. Nevertheless, because the design did not include a control group and inferential statistics were not computed from full individual-level paired data, the result is reported as preliminary pre-post evidence.

DISCUSSION

The study developed and preliminarily evaluated a Treffinger-Ethno-STEAM model supported by DTM for fourth-grade IPAS learning. The baseline result showed that students required explicit support in contextual problem solving. This finding is consistent with international and Indonesian literature indicating that students often struggle when tasks require evidence-based reasoning, strategy selection, and metacognitive evaluation rather than factual recall (Jalaluddin, 2020; Akben, 2020; Istyadji, 2023; Jufrida et al., 2019; Vieira

& Tenreiro-Vieira, 2016; Wen et al., 2020). The model responded to this condition by making problem clarification, idea generation, action, testing, and reflection visible to students.

The expert validation results support the internal coherence of the model. The lowest validation score was obtained for the philosophical and theoretical foundation, which is educationally meaningful. When Treffinger, Ethno-STEAM, and DTM are combined, the model can appear conceptually overloaded unless each component has a clear role. The revised explanation therefore clarifies that Treffinger provides the thinking sequence; Ethno-STEAM provides authentic cultural and interdisciplinary problem contexts, and DTM provides scaffolding and documentation. This division of roles strengthens the theoretical contribution of the study and reduces the risk of treating the model as a simple combination of popular pedagogical terms.

The high practicality ratings indicate that teachers and students considered the product usable. This is important because many instructional innovations fail not because of weak theory but because teachers cannot implement them within real classroom constraints. DTM appears to be the strongest support component in the field implementation because it helped teachers maintain the sequence of learning and helped students move through complex tasks. This interpretation is consistent with scaffolding and multimedia learning theory: well-structured support can help learners process information and regulate their activity during complex learning tasks (Mayer, 2009; Sweller, 1988; Vygotsky, 1978). However, the very high student ratings must be interpreted cautiously because young learners may respond positively due to novelty, social desirability, or teacher presence. Future work should triangulate practicality ratings with observation, time-on-task data, and student interviews.

The moderate N-gain suggests that the model was associated with a meaningful but not maximal improvement. A moderate gain is plausible because the intervention targeted complex outcomes involving both problem-solving processes and cultural-awareness-related reflection. Problem solving generally develops through repeated practice across varied contexts, while cultural awareness requires sustained dialogue and value reflection. The moderate result is therefore educationally defensible and should not be overstated. Compared with studies that report strong gains from STEM, project-based learning, or problem-based learning, the present result may be lower because the intervention integrated multiple demands at once: contextual observation, cultural interpretation, interdisciplinary reasoning, product development, and reflection (Haas et al., 2023; Shanta & Wells, 2022; Zengin et al., 2022). Compared with studies in non-elementary contexts, such as vocational, nursing, or higher education, the present elementary setting requires more teacher scaffolding and age-appropriate simplification (Chiang & Lee, 2016; Chueh & Kao, 2024; Gholami et al., 2021; Sharma et al., 2023).

The cultural dimension of the model contributes by moving local wisdom from background information to problem context and reflection. This addresses a common weakness in culture-based learning: cultural artefacts may be included in materials but not used to guide reasoning or decision making. In the present model, students begin from cultural or local phenomena, analyse the problem, connect it with IPAS concepts, and reflect on cultural meaning. This supports culturally responsive pedagogy and situated learning because students engage with culture as a source of knowledge and values rather than as decorative content (Banks, 2015; Gay, 2010; Ladson-Billings, 1995; Lave & Wenger, 1991).

Several implementation challenges must be considered before broader adoption. First, teachers need professional development on how to facilitate creative problem solving, not merely how to use the DTM. Second, schools with limited digital infrastructure may require offline versions or printed backup materials. Third, the model requires careful classroom management because student design and testing activities can take more time than ordinary instruction. Fourth, cultural integration should be locally adapted; artefacts and practices from one region should not be transferred mechanically to another region without considering community meaning. Fifth, assessment tools need refinement because students rated them lower than other components, indicating that rubric-based reflection may be demanding for Grade 4 students.

Practical Implications

For teachers, the model offers a step-by-step pathway for organising IPAS learning around contextual problems. Teachers can begin with local phenomena, guide students to formulate problems, facilitate idea generation, and support testing and reflection. For curriculum developers, the model provides a template for integrating local culture and STEAM into IPAS modules without losing the structure of scientific reasoning. For teacher education and professional development, the findings suggest that training should focus on questioning strategies, cultural-context selection, formative feedback, and rubric-based assessment. For policymakers and school leaders, the model indicates that digital learning innovation should include pedagogical scaffolding and teacher support, not only the provision of devices or digital content.

LIMITATION AND FUTURE RESEARCH

This study has several limitations. First, the field implementation used a one-group pre-test-post-test design; therefore, maturation, testing effects, teacher effects, and concurrent instruction cannot be ruled out. Second, complete individual-level statistical reporting, including standard deviations, confidence intervals, inferential tests, and effect sizes, was not available in the aggregate dataset used for this manuscript. Third, teacher practicality involves only three teachers, so teacher-level generalisation is limited. Fourth, expert validation involved two validators; a larger panel would strengthen item-level content-validity evidence. Fifth, cultural awareness may be vulnerable to social-desirability bias when measured through questionnaires with young learners. Future research should use quasi-experimental or randomised designs, report separate outcomes for problem solving and cultural awareness, test the model across different grade levels and cultural contexts, examine long-term retention, and analyse the individual contribution of Treffinger, Ethno-STEAM, and DTM through mediation or moderation designs.

CONCLUSION

The study developed a Treffinger-Ethno-STEAM digital learning model for elementary IPAS and provided preliminary evidence of its validity, practicality, and association with improved pre-post learning outcomes. Expert validation showed strong feasibility; teacher and student practicality ratings were consistently high, and field implementation produced a moderate N-gain. The central contribution of the study is an operational instructional pathway that links culturally situated problems, Treffinger creative problem solving, STEAM-based design, digital scaffolding, and reflective assessment. The findings support the model as a promising design for contextual elementary science learning, while stronger causal claims require future research with comparison groups, fuller psychometric reporting, and individual-level statistical analysis.

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