Developing a Design Thinking-Based STEAM Module on Global Hunger Solutions: Empowering Higher-Order Thinking Skills in Middle School Students

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ABSTRACT

This study developed and evaluated a design thinking-based STEAM module entitled "STEM-Driven Hunger Solutions" for junior high school students. The module was designed to address the limitations of conventional STEAM learning materials by embedding human-centered problem solving, interdisciplinary inquiry, mathematical estimation, prototyping, and reflective evaluation into a project on hunger and food security. Using a Design-Based Research approach, the module development integrated five phases of design thinking: empathize, define, ideate, prototype, and evaluate. Expert validation was conducted by three validators using a 12-item validation instrument covering STEM content integration, design thinking structure, pedagogical feasibility, higher-order thinking accommodation, usability, and visual design. The validation results showed an average Aiken's V index of 0.861, indicating high content and construct validity. Two aspects required revision, namely mathematics integration and readability, each obtaining an Aiken's V index of 0.556. Revisions were made by strengthening mathematical estimation activities, clarifying task instructions, and improving the readability of student worksheets. A field trial using a one-group posttest design was conducted with 117 junior high school students in the Greater Jakarta area during the 2025–2026 academic year, organized into 34 groups. Post-implementation evaluation data were obtained from 117 respondents. The results indicated strong attainment of targeted 21st-century skills, particularly critical thinking and problem solving (9.59/10.00), creativity and innovation (9.57/10.00), and interdisciplinary STEAM integration (9.51/10.00). These findings suggest that integrating design thinking into STEAM modules can provide a pedagogically meaningful framework for cultivating students' 21st-century skills. Further studies using pretest–posttest designs, control groups, and broader implementation contexts are recommended to strengthen the evidence of effectiveness.

Keywords: Design Thinking, STEAM Module, Global Hunger Solutions, Higher-Order Cognitive Skills, Middle School.

INTRODUCTION

Twenty-first century skills have become a central concern in secondary education(OECD, 2020). Students are expected to identify real-world problems, process information critically, generate creative solutions, collaborate effectively, and communicate ideas systematically(Kaya et al., 2025). The Merdeka Curriculum, with its emphasis on deep learning, extends the development of these competencies beyond intracurricular activities into co-curricular programs explicitly designed to deepen interdisciplinary understanding and internalize “Profil Lulusan” (Kemdikdasmen, 2025).

The STEAM approach (Science, Technology, Engineering, Arts, and Mathematics) offers a relevant strategy for co-curricular integration given its contextual, interdisciplinary, and problem-solving orientation(Yakman, 2008). Multiple studies confirm that STEAM effectively strengthens creative thinking, problem-solving abilities, and cross-disciplinary knowledge integration(Rahman et al., 2023). This integration potential, however, contrasts with the systemic challenges faced during lower secondary level implementation, where available modules tend to overemphasize final product creation without systematically guiding students through a design thinking process. Consequently, student-generated products often lack a valid foundation in user needs analysis or root cause identification(Rahayu & Nugroho, 2025).

Hunger and food security present a compelling and urgent context for STEAM module integration, globally relevant yet locally relatable, data-measurable, and rich with techno-social challenges(FAO, IFAD, UNICEF, 2023). Leveraging this thematic complexity allows for the mapping of macro-level food production systems and economic dynamics directly onto the tangible, socio-technical problems within the students' immediate geography(Grace et al., 2021). For lower secondary learners, such contextualization shifts the learning paradigm from passive consumption of textbook topics to active, data-driven stakeholder mapping and empirical root-cause analysis.

The novelty of this study lies in integrating Design Thinking as a pedagogical driver within a food security-themed STEAM module(Panke, 2019). The five-stage Design Thinking process—empathize, define, ideate, prototype, and evaluate—serves as a comprehensive thinking framework that guides students from from empathetic understanding to data-driven solution evaluation(Fitriyah et al., 2025). Against this methodological backdrop, the current investigation centers on developing and assessing the initial feasibility of such a module with three primary foci: (1) evaluating content and construct validity through expert judgment using Aiken’s V index; (2) identifying aspects requiring refinement; and (3) describing field test results concerning lower secondary students’ critical thinking, problem-solving, creativity, and interdisciplinary STEAM integration skills. The findings are expected to provide empirical contributions to the development of co-curricular modules aligned with the "Profil Lulusan"demands in secondary education

METHOD

This study employed a Design-Based Research (DBR) approach to develop and validate a Design Thinking-based co-curricular module, the STEM-Driven Hunger Solutions module. DBR was selected for its capacity to bridge the gap between educational design theory and classroom practice through systematic, iterative, and reflective cycles(Easterday et al., 2014). Rather than positioning itself as a pure experimental design, this approach seeks to generate design theory, specifically, how a Design Thinking framework can integrate STEAM competencies and graduate profile values within lower secondary co-curricular contexts, with structural execution spanning the 2025–2026 academic year following the six DBR phases illustrated in Diagram 1.

Diagram 1:
six-phase DBR cycle

01	02	03	04	05	06
Phase 1, problem analysis	**Phase 2, module design**	**Phase 3, expert validation**	**Phase 4, module revision**	**Phase 5, field testing**	**Phase 6, evaluation and reflection**
involved identifying the need for a STEAM module capable of stimulating twenty-first century skills through authentic real-world issues	consisted of structuring the module to integrate the Design Thinking cycle (empathize, define, ideate, prototype, evaluate) with an interdisciplinary STEAM approach.	engaged three STEAM education and instructional design specialists to confirm content and pedagogical validity	implemented improvements based on expert judgment, particularly targeting mathematics integration and instructional readability	deployed the module with 117 lower secondary students organized into 34 collaborative groups	analyzed skill attainment and reflected on the design process to assess the module's instructional quality

Evaluation instruments were developed with reference to the dimensions of the Graduate Profile. Three instruments were employed. First, an Expert Validation Sheet using a 1–4 scale assessed STEM content integration, the Design Thinking framework, pedagogical feasibility, and usability. Expert agreement indices were calculated using Aiken's V. Second, a Project Assessment Rubric measured two dimensions: critical reasoning (ability to process information and ideas) and creativity (product originality). Third, a Post-Implementation Evaluation Sheet captured student perceptions (n = 117) regarding theme relevance and meaningful learning experiences.

FINDINGS AND DISCUSSION

FINDINGS

The primary output of this research is the STEM-Driven Hunger Solutions module, a Design Thinking-based STEAM learning package intended for lower secondary students. The module employs hunger and food security as an interdisciplinary context, guiding students to design technology and engineering-based solutions addressing hunger-related problems in their local surroundings. Developed within a Design-Based Research (DBR) cycle, the module responds to the identified need for STEAM instruction that is more contextual, structured, and oriented toward twenty-first century competencies. It systematically guides learners through five stages: empathize, define, ideate, prototype, and evaluate.

Table 1:
Module Instructional Structure

Design Thinking	Main activities	Skill
Empathize	Discussing the Zero Hunger issue and observing real-world problems.	empathy and social awareness
Define	applying fishbone analysis to identify root causes	critical thinking and causal reasoning
Ideate	formulating STEM-based solutions and prioritizing among alternatives	creativity alongside mathematical reasoning
Prototype	drafting proposals, sketching designs, and building prototypes	collaboration and engineering problem-solving
Evaluate	prototype testing, structured reflection, and infographic creation	communication skills and self-evaluation

Expert validation involved three curriculum and STEAM specialists who assessed content validity across multiple domains using Aiken's V index.

Table 2:
Expert Validation Results (Aiken's V)

Domain	Aspects	Expert Score	V	Interpretasi
STEM Integration	Science	4, 3, 3	0.778	Valid
	Technology & Engineering	4, 4, 3	0.889	Highly valid
	Mathematics	3, 3, 2	0.556	Needs revision
	Interdisciplinary integration	4, 4, 4	1.000	Highly valid

Design Thinking Structure	Empathize & Define	4, 4, 4	1.000	Highly valid
	Ideate	4, 4, 4	1.000	Highly valid
	Prototype & Evaluate	4, 3, 4	0.889	Highly valid
Pedagogical Quality	Critical thinking	4, 4, 4	1.000	Highly valid
	Creative thinking	4, 4, 4	1.000	Highly valid
	Suitability for lower secondary	3, 3, 3	0.667	Minor revision needed
Usability	Readability	3, 3, 2	0.556	Needs revision
	Visual aesthetics	4, 4, 4	1.000	Highly valid

The highest validity scores emerged for interdisciplinary integration (V=1.00), the Design Thinking structure for the Empathize, Define and Ideate stages (V=1.00), pedagogical aspects of critical and creative thinking (V=1.00), and visual aesthetics (V=1.00). Technology and engineering integration (V=0.89) alongside the Prototype & Evaluate stage (V=0.89) also demonstrated very good validity status, as did science integration (V=0.77). This high validity across most domains, however, did not extend to mathematics integration and readability, which fell below acceptable thresholds, requiring substantial revision, while suitability for lower secondary level (V=0.67) indicated the need for minor improvements.

Student project skills were assessed using an analytic rubric designed to capture both critical and creative thinking dimensions, with the corresponding descriptive statistics presented in Table 3.

Tabel 3:
Project Skills Achievement

Indicator	Mean	Median	Min	Max
Critical thinking	75.62	75.00	63.00	100.00
Creative thinking	80.79	88.00	50.00	100.00

Student project skills were assessed using an analytic rubric measuring critical and creative thinking dimensions (Table 3). Project-based assessment yielded mean scores of 75.62 for critical thinking and 80.79 for creative thinking, with corresponding medians of 75.00 and 88.00.

Creative thinking scores showed a wider range (50.00–100.00) than critical thinking scores (63.00–100.00), indicating greater variability in students' creative outputs. The higher mean for creative thinking relative to critical thinking suggests students performed particularly well in generating original ideas and innovative solutions within the Design Thinking framework.

The post-implementation evaluation captured student perceptions regarding their skill development across multiple twenty-first century dimensions, as summarized in Table 4.

Table 4:
Post-Implementation Evaluation Results (N = 117)

Indicator	Score (1-10)	Interpretation
Critical thinking & problem solving	9.59	Very high
Creativity & innovation	9.57	Very high
Interdisciplinary STEAM integration	9.51	Very high

Post-implementation evaluation involving 117 students produced consistently very high scores across three twenty-first century skill indicators (Table 4). Critical thinking and problem solving received the highest average score (9.59/10), followed by creativity and innovation (9.57), and interdisciplinary STEAM integration (9.51). These results indicate that students perceived the module as highly effective in developing the targeted higher-order thinking skills.

DISCUSSION

The present study's findings indicate that a Design Thinking-based STEAM module focused on global hunger solutions demonstrates strong content validity and practical feasibility for secondary education, though targeted refinements in specific domains remain necessary. These results contribute empirical evidence to the growing body of literature on structured STEAM module development and offer actionable insights for curriculum designers seeking to integrate Design Thinking pedagogies into co-curricular programming.

The exceptionally high validity scores achieved for interdisciplinary integration (V=1.00), pedagogical quality for critical and creative thinking (V=1.00), and visual aesthetics (V=1.00) suggest that the module's core design principles align with contemporary educational standards. This alignment echoes earlier work demonstrating that well-structured STEAM modules can effectively integrate multiple disciplines while preserving pedagogical coherenc (Kurniawan & Zulkhi, 2021). The absolute consensus among evaluators across these domains underscores the module's success in operationalizing the module successfully operationalizes the Design

Thinking framework into concrete learning activities that foster higher-order thinking.

The absolute expert consensus (V=1.00) on the empathy, definition, and ideation stages confirms that the module's conceptual framing is highly robust. These represent foundational phases where students develop problem understanding and generate potential solutions. Research by Lathifah et al. (2024) emphasizes that constructivist learning approacheswhich underpin Design Thinking require active student engagement in problem identification and solution generation(Lathifah et al., 2024). This absolute expert consensus (V=1.00) underscores that integrating structured fishbone analysis within the 'Define' phase effectively forces students to isolate variables of food security before ideating prototypes. By anchoring the instructional design in local agricultural data, the module successfully mitigates the common pitfall in lower secondary STEAM materials—namely, the superficial leap to rapid prototyping without rigorous root-cause investigation(Suryaningsih et al., 2024).

The highly valid assessment for critical and creative thinking pedagogy (V=1.00) reinforces the theoretical premise that Design Thinking serves as an effective pedagogical vehicle for developing higher-order thinking skills. Instead of treating higher-order cognition as an abstract byproduct, the module's 5-stage sequential architecture forces an explicit cognitive shift. Students must alternate between convergent analytical reasoning during the 'Define' phase and divergent generative thought during 'Ideation'(Henriksen et al., 2019). This structural workflow embeds cognitive development procedurally. Consequently, critical and creative practices do not occur coincidentally; they are built by design(Dongjin et al., 2024).

Despite these pedagogical strengths, the empirical data reveal critical instructional gaps, particularly in mathematics integration (V=0.55) and readability (V=0.55). The low validity for mathematics integration (V=0.55) uncovers a structural limitation in our initial module design. While it aligns with the broader global trend where mathematics is frequently marginalized in STEAM frameworks(Goos et al., 2023), our specific shortfall stemmed from overemphasizing qualitative stakeholder-mapping during the food security phase. In doing so, we failed to provide explicit scaffolding for operational budgeting and nutritional calculation models, leaving students to rely on intuitive estimations rather than rigorous mathematical analysis.

Readability concerns (V=0.55) likely stem from instructional language exceeding lower secondary students' comprehension levels. Digital and print learning materials for this age group must balance conceptual sophistication with age-appropriate vocabulary and sentence structures(Sweller, 2024). This linguistic requirement accounts for the numerical variance observed in the readability scores (3, 3, 2), which highlight inconsistent assessments, with one expert rating this aspect substantially lower than the others. This inconsistency may reflect variations in experts' expectations regarding target students' reading abilities or differences in how readability was operationalized within the validation instrument.

The moderate validity for requiring only minor revisions to suit lower secondary levels (V=0.67) probably connects to the readability issues. While the module's content and activities may be pedagogically sound, the presentation format and instructional language need adjustments to better align with adolescents' cognitive developmental stage. Effective secondary materials provide clear, concrete instructions with adequate visual support while gradually introducing abstract concepts(Scheel et al., 2022). The moderate validity for this domain suggests the module partially achieves this balance but requires refinement.

Post-implementation evaluation revealed very high student perceptions across all indicators (9.51–9.59/10), indicating strong face validity and student engagement. These results align with research finding that problem-based digital modules enhance student motivation and perceived learning outcomes(Guo et al., 2020). The exceptionally high scores for critical thinking and problem solving (9.59) suggest students recognized the module's effectiveness in developing analytical skills, likely due to the structured fishbone analysis and root cause identification activities during the definition stage.

Mean creative thinking scores from project-based assessment (80.79) exceeded mean critical thinking scores (75.62), suggesting students were more successful at generating novel solutions than at systematically analyzing problems. This pattern may reflect adolescent learners' natural tendencies, who often display enthusiasm for idea generation but require additional support for systematic analysis(Care et al., 2017). Alternatively, this finding could indicate that the module provides stronger support for creative processes than analytical ones, a balance that may require adjustment in subsequent revisions.

The wider range of creative thinking scores (50.00–100.00) compared to critical thinking scores (63.00–100.00) indicates greater variability in students' creative performance. This variability may reflect individual differences in prior exposure to design thinking processes, baseline creativity levels, or differential access to prototyping resources. Similar patterns have been observed in project-based learning, where creative outcomes often vary more substantially than analytical performance due to their reliance on individual expression and resource availability(Suryaningsih et al., 2024).

This study offers several theoretical contributions to STEAM education research. First, it provides empirical support for design thinking as an organizing framework that addresses the fragmentation often observed in STEAM module design. By structuring learning activities around design thinking's five stages, the module creates a coherent narrative guiding students from problem identification to solution evaluation, thereby exemplifying authentic practices of designers and engineers(Henriksen et al., 2019). Second, the findings contribute to understanding how global issue contexts can support interdisciplinary learning in secondary settings. The hunger theme successfully integrated science (agricultural systems), technology (food preservation and distribution technologies), engineering (solution prototyping), arts (infographic design), and mathematics (data analysis and optimization), demonstrating that well-chosen themes can naturally elicit cross-disciplinary connections.

The implementation of this module provides empirical guidance for education practitioners in designing STEAM-based co-curricular activities that adopt Design Thinking principles. The detailed instructional structure presented in Table 1 provides concrete activity descriptions that teachers can adapt to their local contexts. The module's flexibility, a characteristic emphasized by Guo et al. (2020), allows implementation across varying time allocations and resource availability levels. School administrators may find this module particularly valuable for meeting Kurikulum Merdeka requirements to develop graduate profile competencies through structured co-curricular experiences.(Guo et al., 2020).

Several limitations warrant consideration when interpreting these findings. First, although expert validation involved three subject matter specialists, this relatively small panel limits the generalizability of validity estimates. Future research should employ larger expert panels to obtain more stable Aiken's V estimates and to identify systematic patterns in disagreement across different types of experts (e.g., content specialists versus pedagogy experts). Second, the post-implementation evaluation relied on student self-report measures rather than direct assessments of skill development. While student perceptions provide valuable face validity evidence, they do not conclusively demonstrate that the module improved higher-order thinking skills. Experimental or quasi-experimental studies with pre-test–post-test designs are needed to establish causal effects on learning outcomes.

Subsequent research should also investigate the longitudinal effects of Design Thinking-based STEAM instruction on students' problem-solving dispositions and career interests. Early exposure to design processes may influence students' persistence in STEM fields (Hernandez et al., 2018). Deeper investigation is equally warranted to examine how the identified weakness in mathematics integration might be remediated would yield valuable design principles for STEAM module development. Potential solutions include embedding quantitative reasoning tasks within each design thinking stage, providing mathematical scaffolds (e.g., data collection templates, calculation guides), or collaborating with mathematics specialists during module revision

CONCLUSION

This study successfully developed and conducted an initial feasibility evaluation of a Design Thinking-based STEAM module focused on global hunger solutions for secondary school students. Expert validation yielded very high validity for interdisciplinary integration, pedagogical quality for critical and creative thinking, visual aesthetics, and the empathize, define and ideate stages of design thinking. Technology and engineering integration, along with the prototyping/evaluation stage, also achieved very high validity status. Mathematics integration and readability, in contrast, require substantial revision, while suitability for lower secondary level needs minor improvement. Post-implementation evaluation with 117 students revealed very high perceptions of the module's effectiveness in developing critical thinking, creativity, and interdisciplinary STEAM integration. Project-based assessment produced mean scores of 75.62 for critical thinking and 80.79 for creative thinking.

The module offers a validated instructional framework that addresses identified gaps in existing STEAM materials, which often lack systematic guidance through the design process. By embedding learning activities within an authentic global issue context, the module creates meaningful opportunities for students to develop transferable higher-order thinking skills, while simultaneously pinpointing specific areas for refinement, particularly mathematics integration and readability, thereby providing clear directions for subsequent revision cycles. Future research should experimentally test the module's effectiveness on learning outcomes, examine its generalizability across different school contexts, and investigate longitudinal effects on students' dispositions toward STEM fields. Notwithstanding the current limitations, this module represents a promising resource for secondary educators seeking to implement Design Thinking-based STEAM instruction aligned with contemporary curriculum demands for developing twenty-first century competencies.

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