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ORGANIZING MATHEMATICS INSTRUCTION BASED ON STEM EDUCATION TO DEVELOP CONTEXTUAL PROBLEM-SOLVING COMPETENCE IN STUDENTS

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Abstract:
STEM education forges an organic linkage between Mathematics, Computer Science, Science, and Technology, aligning with the objectives of the 2018 General Education Curriculum to foster students' qualities and competencies. Among these, the competence of contextual problem-solving (CPS) is a core capability that STEM-oriented mathematics instruction can effectively cultivate. This study employs literature analysis and synthesis to clarify the fundamental issues of STEM-oriented mathematics education and the components of CPS competence. It then proposes a five-step instructional process tailored to develop this competence, accompanied by a rubric with four levels and 15 indicators for monitoring and measuring student progress. The feasibility of the proposed process and rubric is illustrated through the STEM topic "Mathematics and the Preservation of Cultural Heritage in the Ancestral Land," showcasing how local contexts can be embedded in authentic learning activities to enhance meaning, motivation, and the effectiveness of CPS competence development.

Keywords: STEM education; contextual problem-solving; modeling; instructional design process; assessment rubric

1. Introduction

The integration of STEM in mathematics instruction opens up opportunities to connect modeling, design thinking, and authentic contexts, thereby motivating and adding meaning to the learning process. At the same time, it positions mathematics as a central link among related fields (Science, Technology, Engineering) at the secondary level (Bybee, 2013). However, current practice reveals two critical gaps: (i) difficulty in

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maintaining the "centrality of mathematics" within the integrated task sequences (Just & Siller, 2022; Kristensen et al., 2023); (ii) real-world contexts are often oversimplified, and students are not sufficiently supported in mathematizing or consistently assessed for competency development.

These limitations are particularly evident in grade 10, a transitional stage from intuitive reasoning to formal reasoning and structured modeling. In this study, we approach the competence of contextual problem-solving (CPS) as the ability to mobilize mathematical knowledge to: identify and abstract problems from real-world data; establish reasonable models and assumptions; develop solution strategies; validate and interpret results back into the context; transfer solutions to similar or unfamiliar situations.

This conception synthesizes insights from Realistic Mathematics Education (RME) and mathematical modeling research in mathematics education. On a policy level, it also aligns with the competency-based and quality-oriented direction of the current General Education Curriculum in Vietnam.

The aim of this paper is to propose a direction for organizing mathematics instruction based on STEM education, with the goal of developing CPS competence. This approach is summarized through a concise five-step process (to be named without detailing excessively) and a set of 15 assessment indicators described across a four-level rubric. The instructional approach and tools are designed based on the synthesis of international academic literature on STEM integration and mathematical modeling, and are referenced against standards for mathematics teaching practice to ensure classroom feasibility. This feasibility is illustrated through a local-context STEM topic, in which students gather field data, construct geometric-functional models, validate and interpret solutions under realistic constraints.

Our anticipated contribution is a framework that is both concise enough for immediate application in schools and rigorous enough to serve as a foundation for future impact evaluation and thematic expansion.

2. Research Findings

2.1. Theoretical Foundations

2.1.1. Contextual Problem-Solving Competence

CPS is demonstrated through learners' ability to recognize, analyze, and process real-world situations using mathematical tools in a rational and meaningful manner. Within this process, mathematical modeling competence plays a pivotal role, as it enables the transformation of real-life problems into mathematical models, the resolution of such problems within a mathematical framework, and the interpretation of results back into the original context.

According to the research of Nguyen Thi Mai Thuy (2023), the CPS competence comprises the following components (see Table 1):

Table 1: Component Competencies of Contextual Problem-Solving Competence

Component Competency	Criteria
Competence to understand and construct a real-world model of the contextual problem	- Formulate hypotheses to simplify real-life situations into solvable problems - Identify necessary data; distinguish between relevant and irrelevant information - Clarify objectives and define the requirements of the problem (knowns, unknowns, constraints)
Competence to formulate a mathematical model from the real-world model	- Determine variables based on prior assumptions - Use appropriate mathematical notation for the variables - Establish mathematical relationships (functions, equations, formulas, diagrams, graphs)
Mathematical problem-solving competence	- Apply mathematical methods and tools appropriately - Perform accurate calculations and logical reasoning
Competence to interpret mathematical results	- Draw conclusions for the real-world problem based on the mathematical outcomes - Evaluate the reasonableness of the results with respect to the initial data and practical context
Competence to validate and reflect	- Evaluate the reasonableness and reflect on assumptions, models, and solutions - Propose alternative solutions and assess their optimality - Generalize or formulate similar problems and propose generalized solutions

2.1.2. STEM Education and Mathematics Instruction in High School Aligned with STEM-Oriented Education

2.1.2.1. STEM Education

STEM is an acronym representing four disciplines: Science, Technology, Engineering, and Mathematics. The term is widely used in educational and developmental policies across nations (Sanders, 2009). In the context of education, STEM emphasizes the importance of these disciplines while promoting an interdisciplinary, integrative instructional approach that connects academic content with real-world situations. This integration fosters the formation and development of learners' core qualities and competencies.

STEM education is a cross-disciplinary learning approach where fundamental academic concepts are embedded within real-life lessons. In such learning environments, students are encouraged to apply knowledge and skills from science, technology, engineering, and mathematics to address specific real-world contexts. This helps bridge the gap between school, community, workplaces, and global organizations. STEM education fosters intertwined and cohesive knowledge acquisition through practice-based and problem-solving-oriented learning.

2.1.2.2. Mathematics Instruction in High Schools Aligned with STEM-Oriented Education

In Vietnam's 2018 General Education Curriculum, STEM education is defined as "*an educational model based on an interdisciplinary approach that enables students to apply* *knowledge in Science, Technology, Engineering, and Mathematics to solve real-world problems in specific contexts*" (Vietnam Ministry of Education and Training, 2018).

Mathematics instruction under a STEM-oriented approach involves organizing learning activities that are contextually grounded, allowing students to mobilize and apply mathematical knowledge to solve practical problems. This approach highlights the role of design thinking and mathematical reasoning in proposing, selecting, and evaluating solutions, thereby aligning with the competency-based orientation of the 2018 curriculum.

Through interdisciplinary integration between mathematics and STEM fields, students are provided with opportunities to better understand real-world contexts, enhance their modeling abilities, and develop CPS competence. Mathematics instruction in high school aligned with STEM-oriented education and aimed at developing CPS competence is characterized by the following features: Clearly defined learning objectives based on competency development, with an emphasis on the ability to apply mathematical knowledge to analyze, model, and solve real-world problems; Interdisciplinary integration, particularly between mathematics and fields such as science, technology, and engineering, to support mathematization and the construction of problem-solving models; Mathematics as a tool for understanding and solving real-world problems, helping students comprehend and apply mathematical concepts and methods to explain, predict, and make decisions in meaningful situations; Action- and product-oriented learning activities, wherein students engage in the design, implementation, and evaluation of solutions through mathematical reasoning and processes; Assessment focused on both the process and outcomes of learning, with particular attention to how students analyze context, select mathematical tools, construct models, and verify the reasonableness of their solutions. This reflects the degree to which CPS competence has been developed.

2.2. Developing an Assessment Framework for Contextual Problem-Solving Competence in High School Mathematics Instruction Aligned with STEM-Oriented Education

Based on the guidelines of the Ministry of Education and Training (2018), as well as research by Nguyen Thi Mai Thuy (2023) and Le Thanh Ha (2023), we developed an assessment framework for evaluating CPS among high school students within the context of STEM-oriented education. The framework is outlined in Table 2:

Table 2: Assessment Framework for Contextual Problem-Solving Competence among High School Students

Competence	Indicatos	Level 4	Level 3	Level 2	Level 1
Formulation of mathematical models	Formulating appropriate hypotheses and assumptions to simplify practical situations	Proposes all necessary and contextually appropriate assumptions; clearly explains how these assumptions make the problem solvable, based on mathematical or real-world reasoning.	Proposes appropriate assumptions; explanation is present but lacks depth or clarity in linking assumptions to the problem-solving approach.	Assumptions are somewhat appropriate but include irrelevant ones; explanations lack justification or contain inconsistencies.	Fails to provide appropriate assumptions; proposed assumptions distort the context or do not support problem-solving.
	Identifying relevant data	Accurately identifies and fully selects necessary data; clearly classifies core vs. extraneous data and eliminates irrelevant information.	Identifies most key data, though some may be missing; retains some non-essential information without full justification.	Misidentifies or omits important data; selected information is not well-suited for accurate modeling.	Fails to identify relevant data or uses incorrect information, making it impossible to formulate a correct model.
	Clarifying objectives and constraints of the problem	Clearly identifies objectives, target variables, known and unknown information, and constraints; reformulates the problem using precise mathematical language.	Identifies most requirements and target elements, but the formulation is somewhat incomplete or imprecise.	Only partially identifies objectives; confuses given and unknowns; restates the problem inaccurately or incompletely.	Fails to identify objectives or restate the problem in mathematical terms.
Formulation of mathematical models	Defining variables aligned with assumptions	Identifies all key variables related to the assumptions; clearly explains the meaning, range, and unit (if needed) of each variable within the context.	Identifies the main variables correctly but misses some secondary ones; explanation is somewhat general.	Variables are loosely related to assumptions or include irrelevant ones; the roles of variables in the model are not clearly explained.	Fails to identify relevant variables or selects inappropriate ones, preventing the formation of a usable model.

	Using appropriate mathematical notations	Applies consistent and accurate notation; symbols match the nature of the quantities and initial data, avoiding confusion between variables.	Uses mostly correct notation, though some inconsistencies exist (e.g., switching symbols or overlapping use); meaning is still generally understandable.	Uses incorrect, incomplete, or ambiguous notation; makes it difficult to develop equations or models.	Does not use mathematical notation or uses symbols in a disjointed, unusable manner.
	Establishing accurate mathematical relationships (functions, equations, formulas, diagrams, charts)	Constructs correct and complete relationships; the model accurately reflects the situation, shows clear structure, and allows for effective problem-solving.	Establishes mostly correct relationships, though some links are missing; the model is solvable but needs refinement.	Relationships are flawed or fail to represent the context properly; the model yields unreliable results.	Cannot establish relationships between variables; model is incomplete or unusable.
	Leveraging AI tools for proposing and verifying models with proper validation and interpretation	Effectively leverages AI for variable suggestion and model comparison; validates the model using both data and mathematical reasoning; clearly documents AI usage without over-reliance.	Uses AI support to model effectively, but with limited validation; reasoning for choosing final model is not fully clear.	Over-relies on AI suggestions without verification; model deviates from original assumptions or context.	Does not use AI, or misuses AI in unrelated ways that do not support model building.
Mathematical problem-solving	Selecting and applying suitable mathematical methods and tools	Selects methods that align precisely with the model; executes problem-solving efficiently with clearly presented steps and justified reasoning.	Selects fairly appropriate methods; solution process is mostly correct but may lack coherence or detailed explanation.	Uses methods that are not fully suitable or applies them incorrectly; solution steps are fragmented or lead to incorrect outcomes.	Fails to select appropriate methods; unable to proceed with solving the model.

	Performing accurate calculations and logical reasoning.	Performs operations and calculations accurately; demonstrates strong logical reasoning with well-connected steps consistent with the model.	Minor errors in calculation or logic that do not hinder overall solution; core direction remains correct and fixable..	Significant mistakes in logic or calculations lead to unreliable or incorrect results.	Lacks logical reasoning; serious errors in computation or unable to carry out essential steps.
Interpretation of mathematical results	Drawing well-grounded conclusions for the original contextual problem	Provides correct and complete conclusions; includes appropriate units (if applicable) and clearly explains the real-world significance of the results, directly addressing the problem's requirements.	Provides reasonable conclusions but lacks some elements (units, conditions for application, or contextual meaning); response is mostly on target.	Conclusions are vague; weak contextual interpretation, inaccurate units, or failure to fully address the original problem.	Fails to provide a conclusion or gives a result unrelated to or misaligned with the context.
	Evaluating the results' reasonableness based on given data and real-world conditions.	Compares results with initial data/conditions or real-world expectations; explains the degree of appropriateness using estimation, boundary checks, or validity criteria.	Attempts to evaluate and compare results; reasoning lacks supporting evidence or overlooks key conditions.	Makes observations but lacks justification; mismatches data or fails to align with context.	No attempt to evaluate reasonableness; does not check against real-world or data-based expectations.
Validation and reflection	Systematically reviewing assumptions, models, and solutions; proposing alternative approaches and assessing the optimality of solutions	Performs systematic checks (conditions, steps, context fit); identifies inconsistencies and appropriately adjusts the model or solution.	Performs checks and reflection but not comprehensively; overlooks some comparisons or lacks clarity on how to adjust.	Performs superficial checks; feedback is vague or fails to pinpoint causes of incorrect assumptions/models/solutions.	No checking or reflection on assumptions, models, or solutions.

	Proposing alternative approaches and assessing the optimality of solutions	Provides at least one reasonable alternative solution; compares them using clear criteria (e.g., brevity, accuracy, applicability) and gives justified conclusion on optimality.	Suggests an alternative; comparison is present but criteria are unclear or conclusion lacks precision.	Gives an alternative but it is incorrect or the comparison lacks rationale; optimality assessment is subjective.	Does not propose an alternative solution or fails to assess optimality.
	Formulating similar or generalized problems and outlining general solution strategies	Correctly states a similar or generalized problem; proposes a general solution approach and identifies similarities with the original problem.	States a correct but incomplete version; outlines a general solution but misses some steps or conditions.	Misstates the generalization; proposed approach is inappropriate or disconnected from the original.	Cannot state a generalization or provide any generalized solution strategy.
	Using AI to verify calculations, evaluate results, and refine solutions while acknowledging the limitations and criteria of AI-generated suggestions.	Uses AI to review calculations/reasoning, test data variations or conditions; validates AI-generated results with mathematical reasoning and makes controlled adjustments.	Uses AI to check but tests are limited; validation is unclear; solution refinement is suboptimal.	Over-relies on AI suggestions without verification; adjustments cause errors or misinterpretations.	Does not use AI or misuses it irrelevantly; AI provides no support to review or improve the solution.

2.3. Organizing Mathematics Instruction Aligned with STEM-Oriented Education to Develop Contextual Problem-Solving Competence for High School Students

2.3.1. The Five-Step Instructional Process for STEM-Oriented Mathematics Teaching in High Schools

Drawing from studies by Le Thanh Ha (2023), Le Hong Chung (2023), Ku et al. (2025) and adapting the process to suit high school learners, we propose a five-step instructional model for STEM-oriented mathematics education aimed at developing CPS competence in students, as follows:

- **Step 1: Identify the Topic**

Based on the mathematics curriculum, teachers analyze learning objectives and required knowledge and skills, then align these with STEM education content to determine intersections and cause-effect relationships between mathematical content and STEM competencies. Students are guided to discover or propose real-world problems related to the lesson content, forming a STEM-integrated math topic. Due to the interdisciplinary nature, STEM topics often span multiple lessons or chapters rather than being confined to a single lesson.

- **Step 2: Develop STEM-Oriented Learning Content**

Teachers specify the knowledge objectives of the topic, clearly articulating the STEM skills involved based on each component of the STEM model, and align them with both general and subject-specific competencies. Content must suit the expected time allocation, instructional goals, students' developmental characteristics, and regional conditions. At this stage, it is essential to identify the sequence of learning activities, the objectives of each activity, and the connections between mathematics content and the STEM context.

- **Step 3: Design Learning Tasks**

Teachers design learning tasks based on the topic content, clearly specifying the foundational knowledge required, group collaboration methods, implementation procedures, and timeframe. Tasks may include data collection, experimentation, product design, and presentation. These tasks aim to foster problem-solving, collaboration, self-directed learning, management, creativity, communication, and mathematics-specific competencies.

- **Step 4: Implement the Activities**

Teachers facilitate the implementation of the topic for all students, creating a learning environment that encourages inquiry, communication, collaboration, and sharing during task completion. In the roles of facilitator, guide, and advisor, teachers support students in two key tasks:

a) analyzing and interpreting data, exchanging knowledge, selecting feasible solutions, using appropriate technologies, and communicating effectively;

b) refining models or prototypes, adjusting experimental processes to deepen understanding, and identifying connections to STEM-related careers.

- **Step 5: Assessment**

Assessment occurs on two levels: teachers evaluate students' understanding and competencies through both the process and outcomes of task performance, while also assessing the quality of the STEM topic in terms of feasibility, practicality, accessibility, and engagement. Based on the assessment results, teachers reflect and revise each step to improve the instructional design and learning content.

2.3.2. Illustrative Example of a STEM-Based Lesson: "Creating a Đông Sơn Bronze Drum Model"

This STEM project was conducted within the lesson "Practice and Experience with the Theme: Mathematics and the Preservation of Cultural Heritage in the Ancestral Land," as part of the 10th-grade mathematics curriculum under the Connecting Knowledge to Life textbook series. The project spanned two class periods and followed the five instructional steps outlined previously, as detailed in Table 3:

Table 3: A STEM-oriented learning task sequence for building a bronze drum model: context-based requirements and expected products

Step	Tasks for Students (context-based requirements)	Expected Products / Evidence
Step 1: Identifying the Topic	- Analyze the context: The model is for exhibition/presentation of heritage, with constraints on time, materials, and size. - Define the "real-world problem": How to create a model with accurate shape, pattern placement, structural stability, aesthetic appeal, and cost-effectiveness. - Propose guiding questions (e.g., what scale to use? what structure ensures stability? how to arrange patterns symmetrically?)	- Problem identification and group goal sheet - List of constraints (dimensions, materials, budget, time) - Initial set of evaluation criteria (accuracy, durability, aesthetics, cultural symbolism)
Step 2: Developing STEM-Oriented Learning Content	- Collect reference data on bronze drums (dimensions/images with scale, characteristic features of drum face, body, patterns, etc.) - Apply mathematics for modeling: scale, similarity, circumference, area of circles, modeling drum body with cylinders (and optionally frustums), symmetry, rotations for pattern design - Define the activity sequence and goals of each STEM task (calculation → design → prototyping → testing → refining → communication)	- Reference data table - Table of selected scale ratios and key parameters (e.g., drum face, body circumference) - Flowchart of activities and objectives for each mathematical STEM task
Step 3: Designing Learning Tasks	- Develop group task plans: assign roles (design, calculation, crafting, decoration, communication)	- Task plan and role assignment - Two design proposals with comparison table

	- Create at least two design proposals (varying materials, structure, pattern methods), and select the optimal one using evaluation criteria - Draft technical drawings: scaled dimensions, permissible error margins, list of materials, implementation procedure, risk assessment (e.g., warping, imbalance), and contingency plans	- Technical drawings with scale and tolerance - Materials list Implementation procedure
Step 4: Implementation	- Task 1: Analyze and interpret data, share knowledge, select feasible solutions; use digital tools (e.g., for drawing, recording data, presentations), and collaborate effectively. - Task 2: Build prototype; measure and record deviations (diameter, height, roundness, stability); refine design; adjust testing process to improve; explore STEM-related careers (e.g., industrial design, materials science, museum studies, heritage communication)	- Prototype version 1 with error measurement chart - Experiment log (at least 2 trials + 1 documented revision with justification) - Final model - Notes on STEM career connections
Step 5: Evaluation	- Present a problem-solving report: context → data → calculation → design → testing → refinement → conclusion - Conduct self- and peer-assessment using rubric: accuracy of scale/dimensions, mathematical reasoning, technical quality, aesthetics, cultural relevance, context alignment - Propose improvements (materials, structure, pattern accuracy, exhibition/presentation potential)	- Report (mathematics and design process) - Poster/slide/video for cultural heritage communication - Self- and peer-assessment rubric sheets - List of improvement suggestions

2.3.3. Evaluating Contextual Problem-Solving Competence in Grade 10 Students through the STEM Lesson "Creating a Đông Sơn Bronze Drum Model"

The research team implemented the project with 45 students, divided into 9 groups, who participated in the STEM lesson themed "Creating a Đông Sơn Bronze Drum Model" All groups successfully completed the design and produced final models. The experimental results regarding the assessment of Grade 10 students' CPS are presented in Table 4 and Chart 1 below:

Table 4: Experimental Results on CPS Competence of Grade 10 Students

Component	Indicators	Level 4		Level 3		Level 2		Level 1	
		Quantity	Percentage	Quantity	Percentage	Quantity	Percentage	Quantity	Percentage
Comprehension and construction of real-world models	Formulating appropriate hypotheses and assumptions to simplify practical situations	12	26,67%	18;	40,00%	11	24,44%	4	8,89%
	Identifying relevant data	14	31,11%	20	44,44%	9	20,00%	2	4,44%
	Clarifying objectives and constraints of the problem	15	33,33%	19	42,22%	9	20,00%	2	4,44%
Formulation of mathematical models	Defining variables aligned with assumptions	11	24,44%	19	42,22%	12	26,67%	3	6,67%
	Using appropriate mathematical notations	10	22,22%	21	46,67%	11	24,44%	3	6,67%
	Establishing accurate mathematical relationships (functions, equations, formulas, diagrams, charts)	11	24,44%	18	40,00%	13	28,89%	3	6,67%
	Leveraging AI tools for proposing and verifying models with proper validation and interpretation.	6	13,33%	12	26,67%	17	37,78%	10;	22,22%
Mathematical problem-solving	Selecting and applying suitable mathematical methods and tools	12	26,67%	18	40,00%	12	26,67%	3	6,67%
	Performing accurate calculations and logical reasoning	10	22,22%	20	44,44%	12	26,67%	3	6,67%
Interpretation of mathematical results	Drawing well-grounded conclusions for the original contextual problem	13	28,89%	18	40,00%	11	24,44%	3	6,67%
	Evaluating the results' reasonableness based on given data and real-world conditions.	9	20,00%	17	37,78%	14	31,11%	5	11,11%
Validation and reflection	Systematically reviewing assumptions, models, and solutions	9	20,00%	17	37,78%	14	31,11%	5	11,11%

	Proposing alternative approaches and assessing the optimality of solutions	7	15,56%	15	33,33%	16	35,56%	7	15,56%
	Formulating similar or generalized problems and outlining general solution strategies	8	17,78%	16	35,56%	14	31,11%	7	15,56%
	Using AI to verify calculations, evaluate results, and refine solutions while acknowledging the limitations and criteria of AI-generated suggestions.	5	11,11%	10	22,22%	18	40,00%	12	26,67%

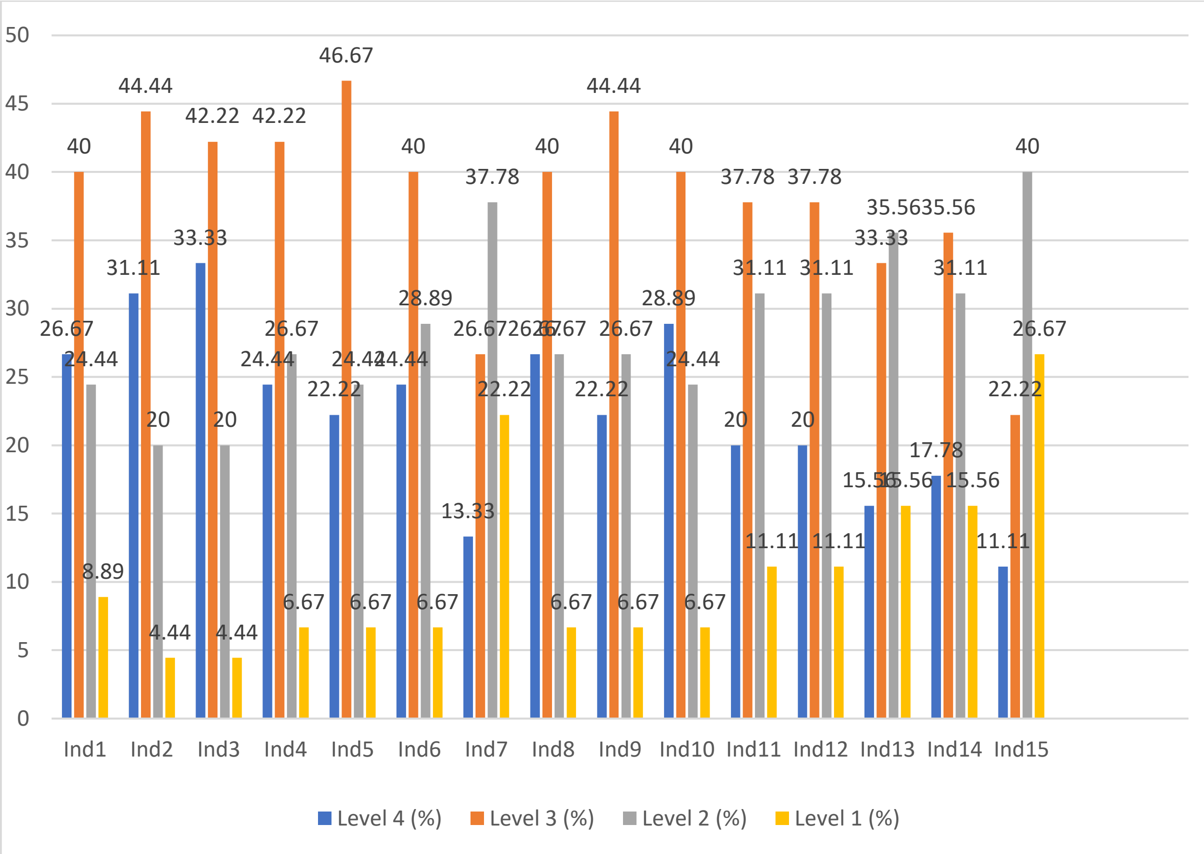

Chart 1: Experimental Results on Grade 10 Students' CPS Competence Assessment

Based on Table 4 and Chart 1, the results indicate that the CPS competence of Grade 10 students was primarily concentrated at Levels 3 and 4, reflecting a relatively strong development across several competency components. Notably, the indicators related to the comprehension and construction of real-world models demonstrated outstanding performance: Indicator 2 (selecting relevant data) and Indicator 3 (clarifying objectives and constraints) both reached 75.55% at Levels 3–4. Indicator 1 (formulating assumptions/hypotheses) reached 66.67% at Levels 3–4. These results show that students made significant progress in "reading" the context, identifying appropriate data, and restructuring situations in a solvable way.

In the subsequent components, formulating mathematical models and problem-solving/interpreting results/a generally positive trend was maintained, with several indicators scoring 66.67–68.89% at Levels 3–4 (e.g., Indicator 9 = 66.66%; Indicator 10 = 68.89%; Indicator 5 = 68.89%). Conversely, indicators within the validation and reflection component, especially those involving AI use, showed notable limitations: Indicator 7 had 60.00% at Levels 1–2, and Indicator 15 reached 66.67% at Levels 1–2.

This suggests that students were not yet strong in validation, optimization, or critically utilizing AI tools with proper reflection and verification.

Overall, the theme effectively supported the development of foundational CPS competence, while abilities related to self-checking, reflection, and responsible use of AI require further enhancement in future implementations.

3. Conclusion

In this study, we proposed and implemented a five-step instructional model for teaching Grade 10 mathematics aligned with STEM-oriented education, aiming to develop CPS competence in students. The pedagogical experiment, conducted with 45 students (organized into 9 groups) on the theme "Creating a Đông Sơn Bronze Drum Model," demonstrated that students engaged actively, completed the required products, and successfully carried out a sequence of problem-solving activities—from analyzing context and modeling to presenting solutions.

The assessment results, based on a four-level rubric framework, revealed that students' CPS competence tended to cluster around the moderate to high levels, especially in components related to understanding the context, selecting relevant data, and constructing models. Overall, the findings affirm both the feasibility and pedagogical effectiveness of STEM-oriented mathematics instruction in enhancing CPS competence among Grade 10 students.

Based on these outcomes, the study recommends broader implementation across diverse contextual themes, alongside further refinement of assessment tools and teaching conditions to ensure the sustainability of learning outcomes.

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Institutional Review Board Statement
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Conflicts of Interest Statement

The authors declare no conflicts of interest.

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